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DEMONSTRATION OF INDUSTRIAL WATER RENOVATION PLANT AT ODESSA, TEXAS

Aerojet-General Corporation
El Monte, California

January 1968

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PB 215 581

ENVIRONMENTAL SYSTEMS DIVISION

DEMONSTRATION OF
INDUSTRIAL WATER RENOVATION PLANT AT
ODESSA, TEXAS

UNITED STATES DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

GRANT NO. WPRD 31-01-67

PROGRESS REPORT NO. 4

JANUARY 1968

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EL MONTE, CALIFORNIA

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Details of illustrations in
this document may be better
studied on microfiche

ACKNOWLEDGEMENTS

The Aerojet-General Corporation gratefully acknowledges the assistance of personnel from the Federal Water Pollution Control Agency; Pomeroy Johnston and Bailey, Civil and Chemical Engineers; and El Paso Products Company. Assistance from technical service representatives from several companies supplying chemicals for water treatment is also acknowledged.

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I. SUMMARY AND INTRODUCTION

A Federal Water Pollution Control Administration grant (Grant No. WPRD 31-02-67) was awarded to the Aerojet-General Corporation for the design, construction, and operation of an industrial water renovation unit at Odessa, Texas. The contract period began 1 January 1967 and extends through March 1968.

A detailed program plan was submitted on 30 March 1967, and subsequently was approved by FWPCA, in which a 6-month demonstration run was to begin 15 September 1967 and to extend to 15 March 1968. Every resource available to the program to date has been devoted toward accomplishing the planned 6-month demonstration run. However, the problems involved in pretreating the Odessa Industrial Complex waste water have been difficult to solve, and a satisfactory demonstration run has not been achieved. Field operations were suspended on 18 December; the combination of freezing weather and pretreatment problems made it impractical to continue operations during the winter months.

The installation of the pretreatment unit was completed 14 September 1967. The following 3 weeks were devoted to correcting minor mechanical problems encountered as the equipment was initially put into operation. On 7 October, the first significant clarifier performance test was begun using a coagulant formulation (150 ppm alum, 100 ppm bentonite clay and 1 ppm Separan NP 10) which had previously demonstrated favorable performance in laboratory jar tests. There was floc carryover into the diatomaceous earth (DE) filters, and this made it almost impossible to sustain continued filter operation at rated capacity. Several other coagulant formulations were tried during the following 8 weeks. A formulation consisting of 45 ppm bentonite clay, 4 ppm Calgon 228D and 2 ppm Calgon 252 was found to eliminate the floc-carryover problem. However, upon startup, severe filter tube plugging occurred which made sustained operation virtually impossible. Filter backwashing proved to be ineffective because of the consistency of the filter cake

formed. Although filter plugging plagued the operation from the beginning of field operations, the extent of the filter plugging was substantially less severe.

Bench-scale reverse-osmosis (R-O) tests were conducted, for a total of 41 days, during this report period, to determine the effects of isopropyl alcohol and pH on membranes, to test membrane performance on pretreated water, and to determine whether periodic membrane flushing improves performance. The bench-scale unit, in which water-and-air flushing on 24-hour cycles was employed, yielded satisfactory membrane performance.

Operation of the 10,000-gpd R-O unit, on pretreated water feed, was first attempted on 2 December. Filter backwashing problems and freezing weather interrupted the R-O operation, and the R-O run was discontinued on 11 December.

II. REVERSE-OSMOSIS UNIT OPERATION

A. SIMULATED OPERATION

The reverse-osmosis unit was first put into simulated operation (without the membrane plate stack) on 7 October 1967. The purpose of the simulated operation test was to determine whether any mechanical difficulties would occur in the R-O unit upon exposure to Odessa waste water feeds. The simulated operations test was not continuous, since it was necessary to discontinue R-O unit operation several times to effect required modifications and for minor maintenance. It was also necessary, on several occasions, to interrupt the test because of pretreatment equipment problems which resulted in an inadequate supply of feed water to the R-O unit.

After the modifications were complete, the R-O unit was found to be mechanically sound, and the simulated operational test was terminated on 28 October 1967.

B. MEMBRANE PLATE STACK PERFORMANCE TESTS

The R-O membrane plate stack was tested, prior to shipment, on a 1/2% sodium chloride solution; it was tested again, on a similar solution, at Odessa to ensure that there had been no damage to the membranes during shipment. The preshipment test report is included as Table II-1.

In Table II-2, the preshipment test data are compared with the test data obtained at Odessa. The actual membrane fluxes and permeations differ because of the different operating conditions, i.e., temperature, pressure, and recovery ratio. To facilitate a good comparison, adjusted fluxes and permeations were also calculated; the actual data was adjusted, according to theoretical relationships (see Appendix A) to a selected set of conditions, i.e., 500 psi, 77°F, and 70% product recovery.

The adjusted fluxes and permeations show that there was no significant difference in the plate stack performance, after arrival at Odessa, as compared to the plate stack performance prior to shipment.

C. PLATE STACK FLUSHING TEST

Before starting up the R-O unit, the decision was made to use water-and-air flushing for 15 min on 12-hour cycles, based on the results of Bench-scale

TABLE IV-1

AEROJET-GENERAL CORPORATION
WATER PURIFICATION SYSTEMS
PRESHIPMENT PERFORMANCE TESTS

MODEL 1-560B-3 CUSTOMER FWPCA

SERIAL NO. 932497* DESTINATION Odessa, Texas

FEED SOLUTION Softened Azusa Tap Water + Sodium Chloride

* This unit used for stack check-out at VKC. Unit #932490 will be used in Odessa.

MECHANICAL PERFORMANCE

Date	Time	Pressure, psi			Temp. °F	Flows, gpm			% Rec.	*** Flux gfd	Prod. Rate gpd	Prod. Meter gal
		Pump Suct.	Cell in	Cell ΔP		Prod.	Waste	By-Pass				
10/17/67	1145				Start Up Unit							
"	1245	31	430	**	86	6.88	7.85	-0-	46.7	16.5	9900	13,390
	1315	31	420		89	6.87	7.8	-0-	46.8	16.5	9900	13,430
"	1345	30	420		92	6.9	7.84	-0-	46.8	16.6	9930	13,626
"	1415	30	410		93	6.85	7.85	-0-	46.6	16.4	9860	13,827
"	1445				Shut Down Unit							

** No Way To Measure On This Unit.

*** Based on 600 Ft^2 Membrane

SALT REJECTION PERFORMANCE

Date	Time	Specific Resistance (Ohm-cm x 10)						TDS, ppm			% Salt Rejection
		Feed	°C	Prod.	°C	Waste	°C	Feed	Prod.	Waste	
10/17/67	1300	210	28	940	29	130	29	4925	957	8000	80.6
"	1330	210	28.5	920	29	130	29	4875	977	8000	80.0
"	1400	205	30	910	30	123	30	4875	970	8350	80.1
"	1430	200	31	900	32	118	31.5	4900	948	8490	80.7

TABLE II-2

REVERSE-OSMOSIS UNIT TESTING

Test Parameters	Odessa Tests No. 1 11/21/67	Odessa Tests No. 2 11/21/67	Preshipment Test[1] 10/17/67
Test duration, hours	2.2	1	3.2
Operation pressure, psi	600	430	420
Feed water temperature, °F	70	70	86
Feed water conc., ppm as NaCl	5340	5380	4887
Reject stream conc., ppm as NaCl	12,675	8400	8220
Product concentration, ppm as NaCl	1250	1235	964
Unit production rate, gal/day	11,100	7630	9890
Cell feed rate, gal/day	14,400	14,400	21,100
Product-to-feed recovery, %	77	53	46.7
Actual membrane flux, gfd	18.5	12.8	16.5
Permeation based on feed, %	23.4	23.0	19.7
Adjusted membrane flux,[2] gfd	17.3	16.4	16.6
Adjusted permeation,[3] %	21.9	23.9	25.3

Notes: (1) See Table II-1 for complete preshipment test data.

(2) Flux rates adjusted to 500 psi, 77°F, and 70% product recovery (see Appendix A).

(3) Permeation adjusted to 500 psi, 77°F, 70% product recovery and corrected flux (see Appendix A).

Test No. 3 (see Section IV,C). Next, some flushing experiments were conducted to determine a satisfactory method for carrying out water-and-air flushings. No satisfactory method was derived. In every case, the air separated from the water in the cell dome, and the reject stream showed no evidence of entrained air. It was concluded that water-and-air flushing is impractical with the existing cell configuration. For this reason, a 15-min flush every 12 hours, using water only, was adopted as the next best alternative.

D. ON-STREAM PERFORMANCE

The R-O unit was put on-stream on waste water feed for the first time on 2 December 1967, and was operated intermittently through 11 December. The startup date was selected because this was the first time that high-density floc was produced in the clarifier. The high-density floc resulted from the use of a new coagulant, Calgon D228, which became available to the Odessa program on 2 December (see Section III). Floc carryover from the clarifier was almost totally eliminated.

Filter backwashing problems and freezing weather forced frequent shutdowns of the R-O unit. The actual R-O operating time achieved is shown in Table II-3.

The performance data of Table II-3 shows a significant 54% decline in adjusted membrane fluxes during this operating period.

Two bench-scale units were operated under the same operating conditions and the same periods of time as the demonstration R-O unit. The bench-scale units had adjusted initial fluxes averaging 29.5 gfd, and adjusted final fluxes averaging 20.1 gfd, a decline of 32%.

TABLE II-3

REVERSE-OSMOSIS UNIT OPERATION AND PERFORMANCE

Start-up		Shut-down		Operating Hours	Reason for Shut-downs
Date	Time	Date	Time		
12/2	1815	12/2	2210	3.9	Filter backwash problems
12/3	0000	12/3	0045	0.8	Frozen Cl_2 feeder & filter prob.
12/10	0000	12/10	0500	5.0	Frozen pipe lines
12/10	1140	12/10	1700	5.3	Filter backwash problems
12/10	1815	12/10	2400	5.8	Flush period & filter problems
12/11	0030	12/11	1215	11.8	Filter pump seal failure
12/11	1430	12/11	1845	4.3	No feed water due to El Paso Products Co. experiments
		Total Operating Hours		36.9	

R-O UNIT PERFORMANCE

Date	12/2	12/10	12/11
Time	1845	0215	0100
Feed temperature, °F	59	48	50
Operating pressure, psi	600	640	720
Production rate, gal/day	9000	4850	3910
Average permeation, %	12.75	-	-
Membrane flux, gfd	16.0	8.66	6.99
Adjusted flux,* gfd	21.3	13.1	9.7
Recovery as product, %	62.5	33.7	27.2

*Adjusted membrane fluxes are the fluxes corrected to 700 psi, 77°F, and 70% recovery ratio (see Appendix A).

III. PRETREATMENT UNIT OPERATION

The first startup attempt of the pretreatment unit began on 14 September 1967 (see Appendix B for start-up procedure). Operating difficulties made it necessary to discontinue operations several times during the first 3 weeks. By 7 October, the mechanical performance of the pretreatment equipment was improved to the point where feed to the clarifier could be sustained.

Minor mechanical improvements were made to the pretreatment unit, throughout the operating period, to improve performance. The major efforts, however, were directed toward achieving uniformity of the effluent water from the clarifier and DE filters.

Pretreatment unit operations were discontinued on 18 December 1967, and preparations made for an extended shutdown.

A. CLARIFIER PERFORMANCE

A coagulant jar-test program, for evaluating coagulant formulations, was initiated (see Section V) to find better coagulant formulations for use in the clarifier. The control parameter used for monitoring clarifier performance is the turbidity of the clarifier effluent. A plot of the turbidity measurements made during the operating period is shown in Figure III-1.

By consulting with El [illegible] Products Company operating personnel concerning their operating experience with diatomaceous earth filters on waste-water feeds, it was learned that filter cycles are usually too short for practical operation, i.e., less than 8 hours, if the feed turbidity exceeds 3 Jackson turbidity units (JTU). An objective was then established to derive an operating procedure, and coagulant formulation, which would sustain clarifier effluent turbidities not exceeding 3 JTU. The changing characteristics of the feed water made this task a difficult one.

Occasionally, the clarifier effluent turbidities did meet the above criteria, but not for any extended period of time. Coagulant formulation changes, based on jar-test results, also failed to yield the expected improvements. Floc carryover in the effluent water was the most significant problem. This problem persisted until 2 December 1967.

The coagulants used during the period between 2 December and 14 December (Calgon 228D, Calgon 252, and clay) solved the floc carryover problem. However, the turbidities were still poor (see Figure III-1). Jar tests, conducted over the previous 3 weeks, had shown that these coagulants produced lower turbidities than any other combination of coagulants tested (see Section V).

B. FILTER PERFORMANCE

The diatomaceous earth filters were first put into operation on 20 September 1967, and operated intermittently through 14 December. With the wide variations in filter feed water (clarifier effluent), it was impractical to attempt any meaningful long-term performance test of the filters. The filters were operated, when needed, to accomplish the following:

- To detect mechanical deficiencies in the filter systems so that required modifications could be made
- To supply feed water for the bench-scale tests (see Section IV)
- To provide feed water for simulated operation of the R-O unit (see Section II,A)
- To provide feed water for R-O unit operation - 2 December through 14 December (see Section II,D).

Filter cycles were variable, ranging from 20 min to 24 hours, when the R-O unit was in operation. Longer cycles sometimes occurred when water was required only to maintain feed to the bench-scale test units, i.e., 25 gal/hour.

Performance of the DE body feeder was unreliable, and the feeder was inoperative most of the time until the feeder diaphragm pump was replaced with an eductor system. Reliable body-feeder performance was established 6 December 1967.

Plugging of the filter tubes was a major operating difficulty. The stainless steel tubes gradually became plugged until it was no longer possible to remove the filter cake from the tubes during backwashing cycles. When this happened, it was necessary to disassemble the filters and clean the tubes with an air/water blast or with high-pressure steam. This was done three times during the report period, on 11 November, on 4 December, and on 14 December. This cleaning operation required 4 man-days of labor each time.

Several methods for chemically cleaning the filter tubes were attempted, but all failed. The chemicals used included caustic soda, inhibited muriatic acid, Oakite No. 32, and tri-sodium phosphate. Several precoat formulations were also tried, with the objective of protecting the tubes from fine particulate matter, with no success.

IV. BENCH-SCALE TESTS

Bench-scale R-O tests were performed to test membrane performance on Odessa waste waters. The equipment functioned well and no significant maintenance problems were encountered. Three bench-scale tests were conducted during this report period. The following paragraphs are a discussion of each of these tests.

A. BENCH-SCALE TEST NO. 1

Bench-scale Test No. 1 began 30 August 1967, and ended 15 September 1967. The primary objectives of this test were to determine the effects of isopropyl alcohol and pH on membrane performance. In addition, the test was designed to verify the effectiveness of chlorination in protecting membranes against bacteriological attack, and to identify any problems caused by the "varnish-like" substance in the waste water. The original test plan, and all procedures used in this test, have been previously presented (Ref. 1c, Appendix A).

1. Deviation from Original Test Plan

The original test plan specified four test periods of 5 days each. It was found necessary to deviate slightly from the test plan during the first two test periods. These deviations have been described in detail, and the complete results of Test Period I has been presented in a previous report (Ref. 1c, Section III).

After reviewing the results of Test Period I, it was decided to revise Test Period III, eliminating isopropyl alcohol from two of the test conditions to provide more conclusive data regarding whether the isopropyl or low pH is responsible for the rapid flux decline previously observed. The revised test plan is shown below:

	Assignment of Test Combination				
Test Period	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
I	E	D	B	C	A
II	E	B	D	A	C
III	E	C	A	F	G

After Test Period III, it was decided to discontinue Bench-scale Test No. 1. Pretreatment unit startup preparations made it impossible to continue to supply the type of feed water needed.

The feed conditions for each of the test combinations are presented in the following tabulation:

Test Combination	Blended Feed pH	Isopropanol Added to Feed, ppm	Membrane Change After Each Test Period
A	5 ±0.5	10	Yes
B	5 ±0.5	1000	Yes
C	4 ±0.5	10	Yes
D	4 ±0.5	1000	Yes
E	7 ±0.5	0	No
F	5 ±0.5	0	-
G	4 ±0.5	0	-

2. Analysis of Feed Water

The feed water used in Bench-scale Test No. 1 was obtained from a single feed batch, prepared in the equalizing tank (a 13,500-gallon portable swimming pool). Therefore, the feed water was identical for all three test periods, with the following exceptions:

- Calcium hypochlorite was added periodically to maintain a chlorine residual of about 1.5 ppm. This increased the total dissolved salt content, as calculated from conductivity measurements (see Section VII,B), from 7900 ppm to 8480 ppm.
- Some changes in the feed water undoubtedly occurred over the 16-day test period. as a result of exposure to air and slow chemical reactions. No attempt was made to detect these changes.
- The feed water used during the final day of the test, 15 September, contained skimmer effluent water from the pretreatment unit. The first start-up attempt of the pretreatment unit was in progress at that time.

Analyses were made on the feed water batch prior to start-up of Bench-scale Test No. 1. The following tabulation presents the results of these analyses:

Iron	0.34 ppm
Manganese	0.7 ppm
Calcium	240 ppm
Magnesium	48.6 ppm
Hardness (as calcium carbonate)	800 ppm
Total alkalinity (as calcium carbonate)	120 ppm
Sulfate	1300 ppm
Turbidity	8.75 JTU
Settleable solids	None
Isopropyl alcohol	1.8 ppm
Millipore test	50 ml in 3 min
Presumptive coliform*	Negative

3. Test Results from Bench-scale Test No. 1, Test Periods II and III

The results of Test Periods II and III are shown in Figures IV-1 and IV-2. The feed water for the last day of Test Period III contained skimmer effluent from the pretreatment van. This accounts for the drastic changes shown near the end of the test.

During Test Period II, the lowest pH values corresponded with the lowest flux rates. A significant flux decline occurred in some of the test cells before the first flux reading was taken (1-1/2 hours after start of test). This initial flux decline was more pronounced for the lower pH values.

After Test Period II, the membranes from both Units 4 and 5 had large particles on them, indicating faulty filters. Upon inspection of the filters, the leak source in Unit 5 was found and corrected. The leak source in Unit 4 was not found, but new filter elements were installed in all filters. After Test Period III, large particles were found on the membranes from Unit 1. These membranes had been in service for 15 days. It is not known whether these large-particle deposits occurred during Test Period III, or during an earlier test.

*The presumptive coliform test was run on a sample taken after five days of operation on Bench-scale Test No. 1.

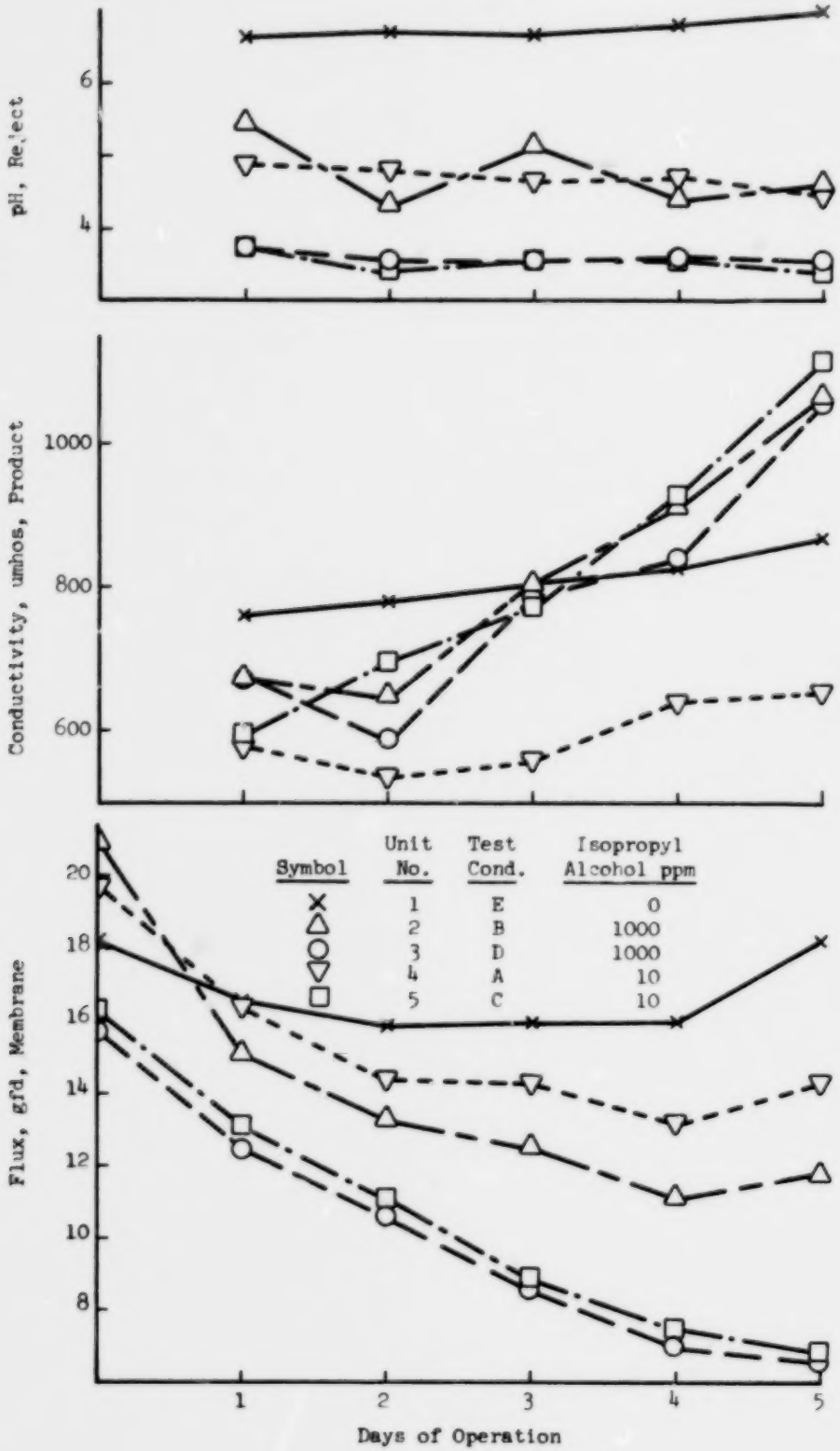

Figure IV-1. Bench-Scale Test 1 - Test Period II

8220-68-736

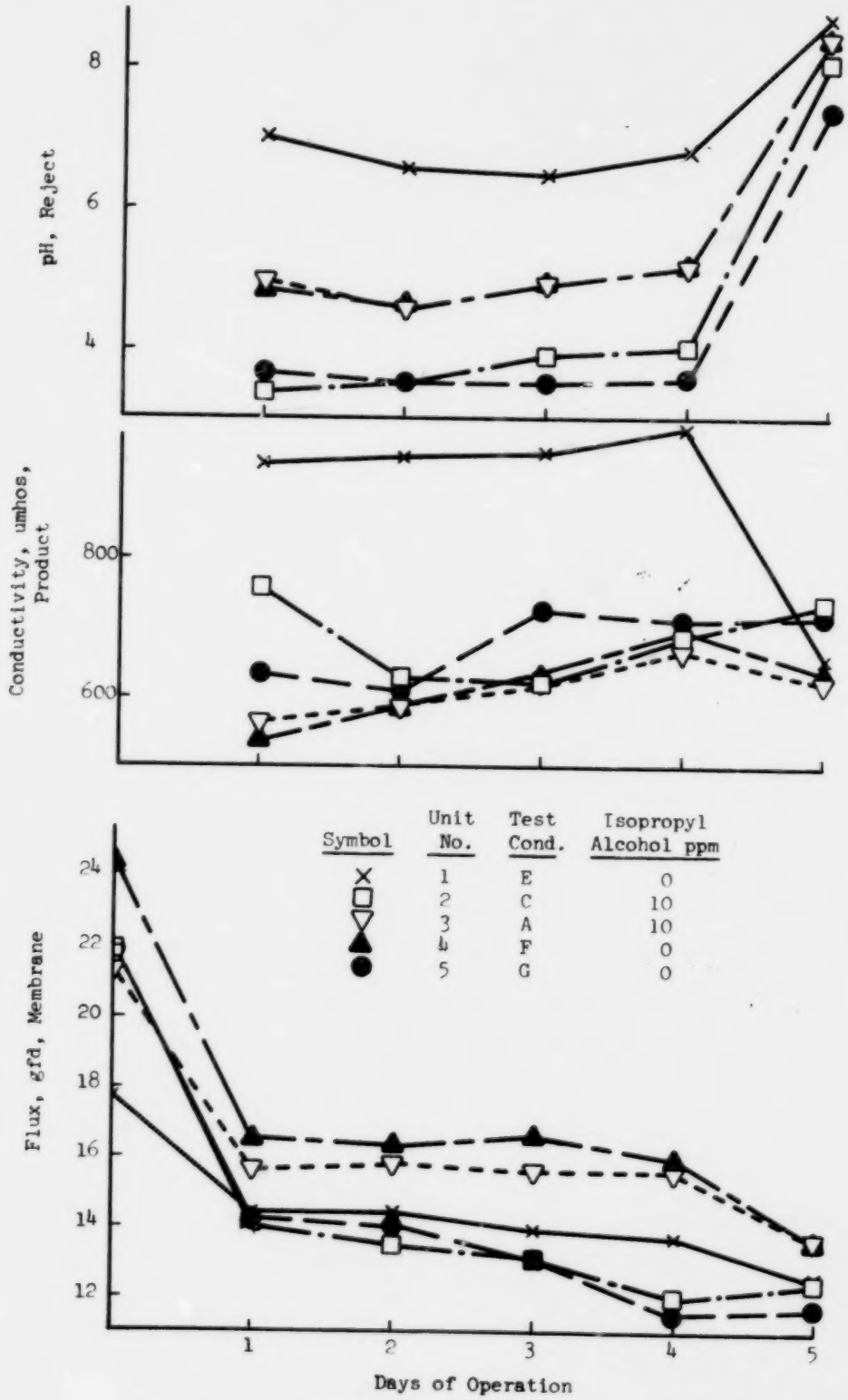

Figure IV-2. Bench-Scale Test 1 - Test Period III

0220-68-737

Except for the large particles, all the membranes from Test Period II had a similar appearance (i.e., light brown in color, deposits loosely adhered to membranes, and some deposit penetration into the membranes). The membranes from Test Period III all had the same appearance as those from Test Period II, except for Unit 1. The deposits on the Unit 1 membranes were dark brown and were not as dense. Some areas of the membranes from Unit 1 were free of deposits. There seemed to be very little penetration of the deposits into the membranes in Unit 1.

B. BENCH-SCALE TEST NO. 2

Bench-scale Test No. 2 was conceived as a membrane flushing test. The purposes of the test were to determine whether the pretreated water from the demonstration unit was of a quality level that could be processed by RO, and to determine whether periodic membrane flushing would improve R-O performance. The detailed test plan for Bench-scale Test No. 2 is included as Appendix C.

Bench-scale Test No. 2 began 23 October 1967 and was aborted 26 October, after only 63 hours of operation, because of the excessive initial flux decline. The membranes were removed and inspected. There was no indication of damage nor were there any significant deposits. The test results for this 63-hour period are shown in Figure IV-3.

During the test, the feed temperature dropped from 89°F, initially, to 59°F, at the end of the run. This temperature difference alone could account for a 42% flux decline (see Appendix A). The actual flux decline averaged only 38%, indicating that no significant membrane deterioration had taken place, and that the test was unnecessarily aborted.

The test duration was too short to reach any significant conclusions regarding pretreated water quality or benefits derived from flushing procedures.

C. BENCH-SCALE TEST NO. 3

New membranes were installed in all of the bench-scale test cells, and a new test initiated 25 October 1967, following the same test procedure outlined for Bench-scale Test No. 2 (see Appendix C). The test was continued for 588 hours and was finally terminated on 20 November. It was necessary to terminate the test at this time in order to make preparations for the performance test of the R-O membrane plate stack.

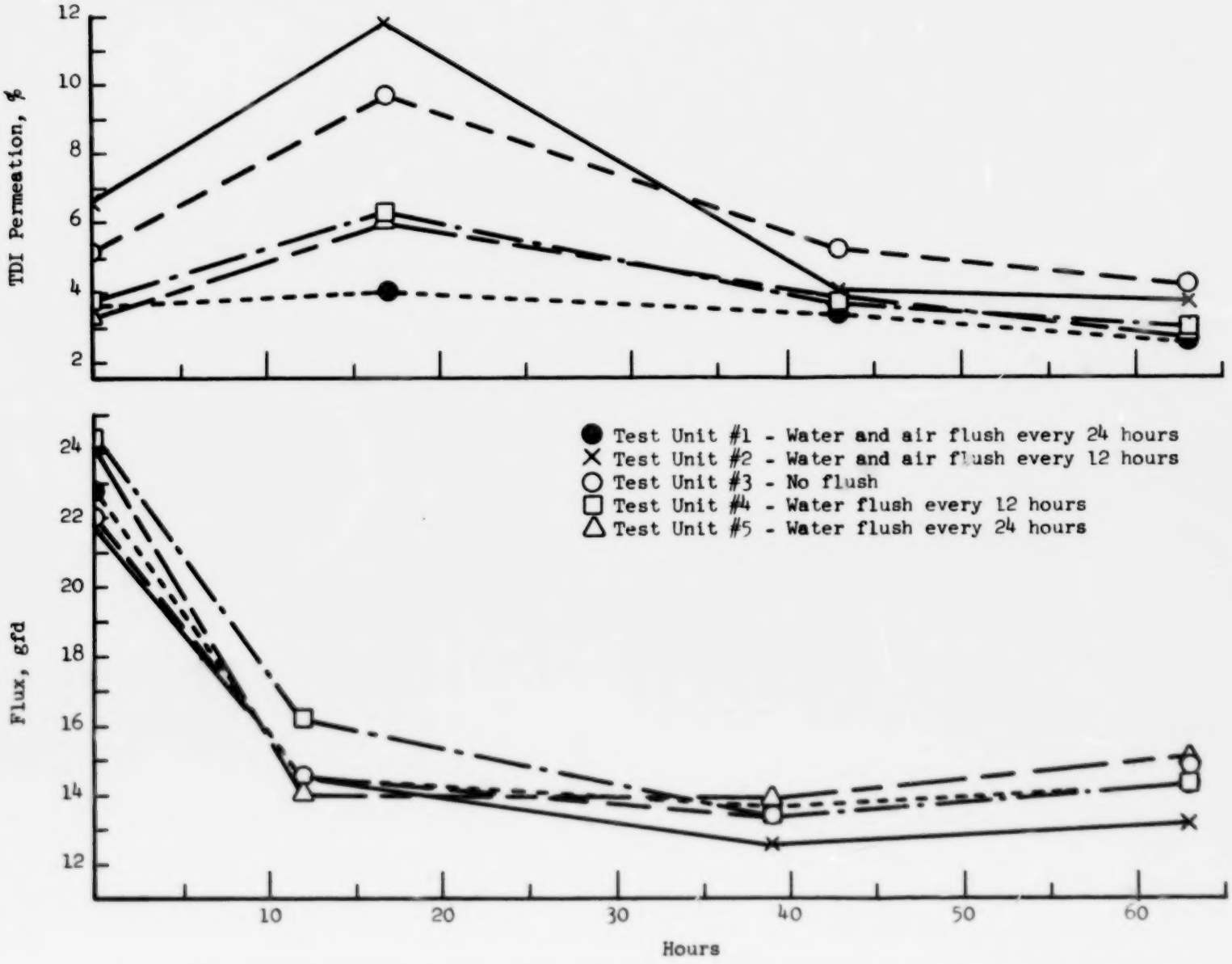

Figure IV-3. Bench-Scale Test 2 - Membrane Fluxes and Permeations

1. Test Results

The results of Bench-scale Test No. 3 are shown graphically in Figure IV-4; fluxes, corrected for temperature differences, are also shown in Figure IV-5.

Only one test unit, Unit 1, operated the entire test period with no significant degradation. Unit 1 had both air and water flushings every 24 hours.

Unit 2 exhibited an excessive flux-decline rate, after about 100 hours of operation. This unit also had both water and air flushings, but on a 12-hour cycle. The flux rates in Unit 2, leveled off after about 400 hours of operation and no further decline was observed.

Unit 3, with no flushing, and Unit 5, with water flushing in 24 hour cycles, both exhibited excessive flux decline rates after about 300 hours of operation. An investigation into possible feed-water changes revealed that, on 8 November, at approximately the same time the rapid flux decline rates for Units 3 and 5 began, waste water from the General Tire Plant was re-admitted into the combined waste system. The General Tire waste water had not been in the system at least since the beginning of Bench-scale Test No. 3.

After about 300 hours of operation, Unit 4 also exhibited an increased rate of flux decline. However, the rate of decline was not so great for Unit 4 as it was for Units 3 and 5. Unit 4 was flushed with water on 12-hour cycles.

2. Examination of Membranes

An examination of the membranes, after the Bench-scale Test No. 3 was terminated, revealed the following:

Unit No.	Type of Flushing	Amount of Deposits	Deposit Adhesion
1	Water and air, 24-hour cycle	Slight	Fair
2	Water and air, 12-hour cycle	Very slight	-
3	None	Heavy	Poor
4	Water flush, 12-hour cycle	Moderate	Poor
5	Water flush, 24-hour cycle	Heavy	Poor

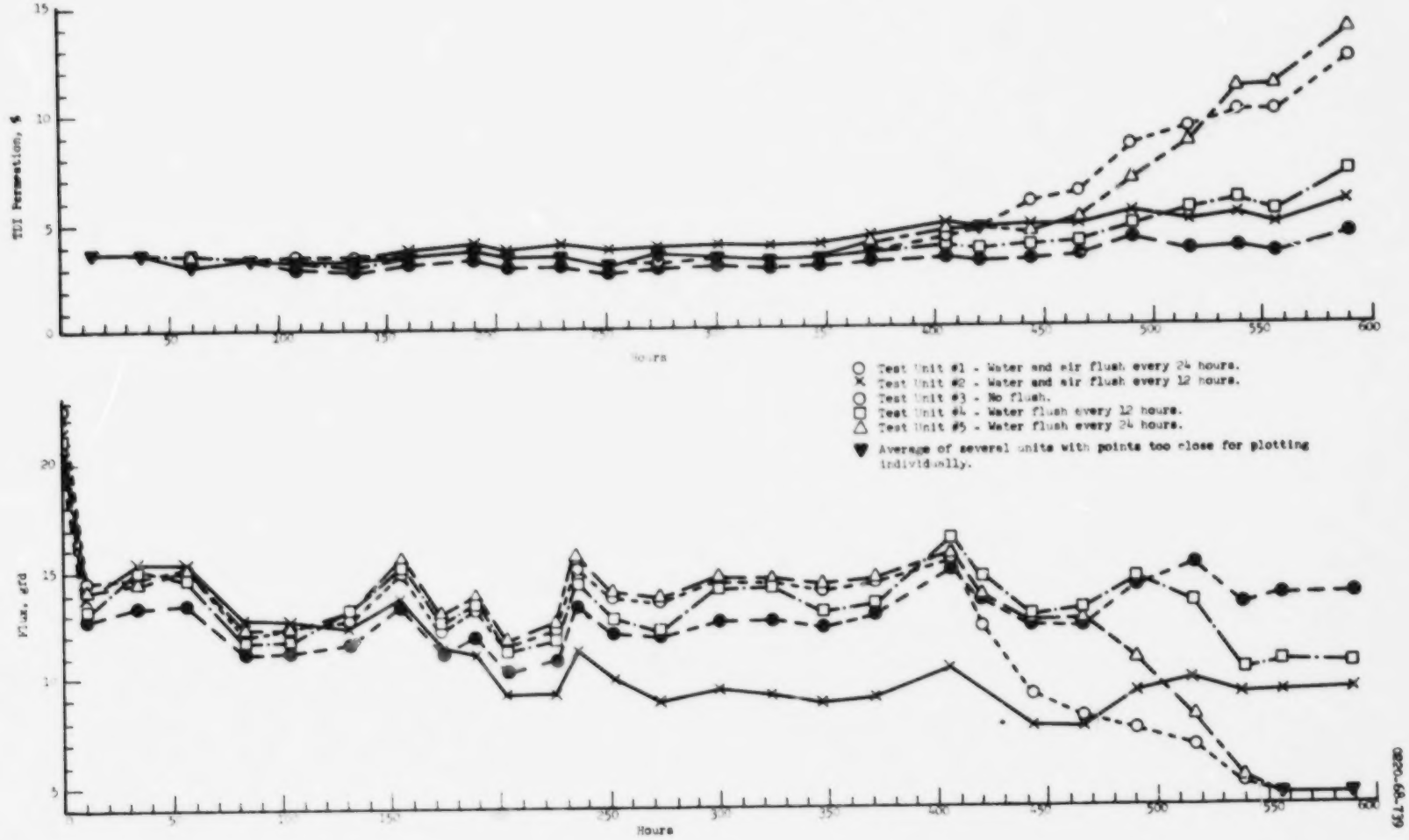
TDI Permeation, %
Hours
Flux, gfd
Hours
Test Unit #1 - Water and air flush every 24 hours.
Test Unit #2 - Water and air flush every 12 hours.
Test Unit #3 - No flush.
Test Unit #4 - Water flush every 12 hours.
Test Unit #5 - Water flush every 24 hours.
Average of several units with points too close for plotting individually.
0820-68-799

Figure IV-4. Bench-Scale Tests 3 - Membrane Fluxes and Permeations

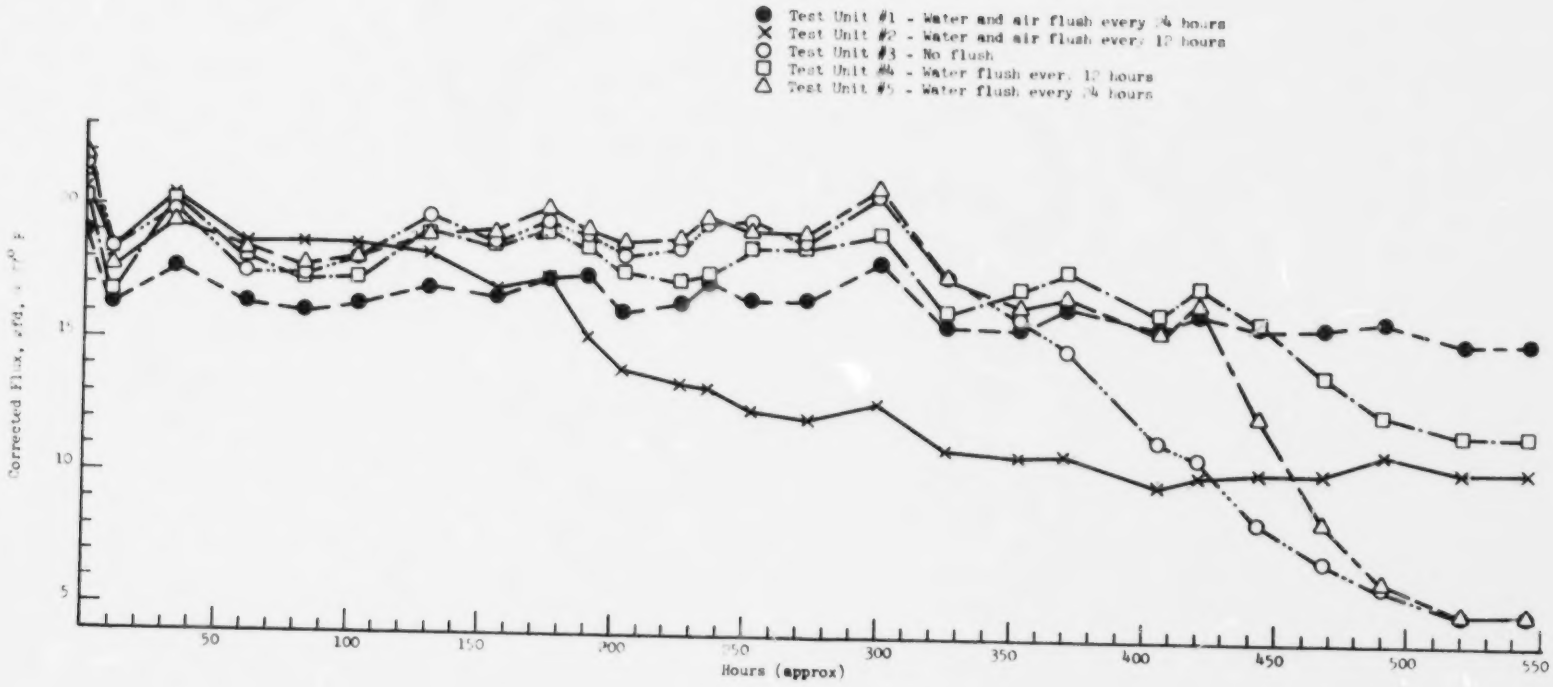

Figure IV-5. Bench-Scale Test 3 - Membrane Fluxes Corrected to 77°F

V. FLOCCULATION JAR TESTS

Flocculation jar tests were conducted at Odessa in a continuing effort to find a coagulant formulation which would eliminate the clarifier flox carryover, and which would reliably produce low-turbidity clarifier effluent. Thirty-nine jar tests were conducted during this report period. The results of the tests were used to select the coagulant formulations used in the demonstration unit. Test reports of each of these tests are included as Appendix D.

The first three jar tests were conducted to evaluate weighting agents. The use of weighting agents resulted in faster - settling times. Two grades of diatomaceous earth produced better results than bentonite clay.

Jar tests No. 5 through No. 9 were conducted to find the best combination of coagulant dosages (using alum, filter-cel diatomaceous earth, and Separan NP 10) to use on Odessa wastewater feeds. The results were erratic.-

Jar tests No. 10 through No. 20 were conducted to evaluate the performance of Dow purifloc coagulants (A-21, A-22, and A-23). Formulations using purifloc coagulants produced poorer results than formulations using Separan NP 10.

Jar tests No. 21 through No. 28 were conducted to evaluate the performance of several coagulants (Calgon 252 and 454; Nalco 670, 672, 673 and 680, Dow puriflox A-21; and alum). Calgon 252 was selected, from the results of these tests, as the best secondary coagulant to use in order to obtain faster flox settling rates.

Jar tests No. 29, 34, 36, 37, and 38 were conducted to evaluate Calgon 228D as a primary coagulant. Calgon 228D produced better results than any other coagulant tested.

Jar tests No. 30 through 33 were conducted to find the best sequence and timing of coagulant addition. The addition of a seeding agent (bentonite clay) first produced the best results.

Jar tests No. 35 and 39 compared bentonite clay and Calgon 25 clay for effectiveness as seeding agents and weighting agents. The results were inconclusive.

VI. FACILITIES

A. DESCRIPTION OF FACILITIES

The facilities constructed for the demonstration program consist primarily of two trailers, one housing the pretreatment equipment and R-O unit; and the other housing a bench-scale R-O installation, a control laboratory, and a field office. A 13,500-gallon equalizing tank, and the chlorinator were field-installed on the ground adjacent to the trailers. Figure VI-1 shows the Odessa installation. Figure VI-2 is a close-up view of the pretreatment trailer, including the R-O unit. Figure VI-3 shows the bench-scale facilities and control laboratory.

Simplified flow diagrams of the pretreatment unit, R-O unit, and bench-scale test unit are shown in Figures VI-4, VI-5, and VI-6, respectively. Each of the major processing steps are identified on the flow diagrams.

B. PLANT INSTALLATION

The field support van was installed and put into operation during the previous report period (see Reference 1c, Section II). The demonstration unit trailer arrived at the Odessa plant site on 7 September 1967; installation work began the same day and was completed by 14 September. Two strip chart recorders and the trailer air conditioning unit were damaged in transit and were subsequently repaired.

C. MODIFICATIONS

The following items of equipment were modified to improve performance:

- Centrifugal pumps
- Equalizing tank agitator
- Coagulant feeders
- Bentonite clay feeder
- Clarifier
- D-E filter system
- R-O unit

Major operational difficulties were encountered with the D-E filter system and the following changes were made:

- An eductor-type precoat system was installed.
- An eductor-type body feeder was installed.
- Piping changes were made to improve the blowdown operation

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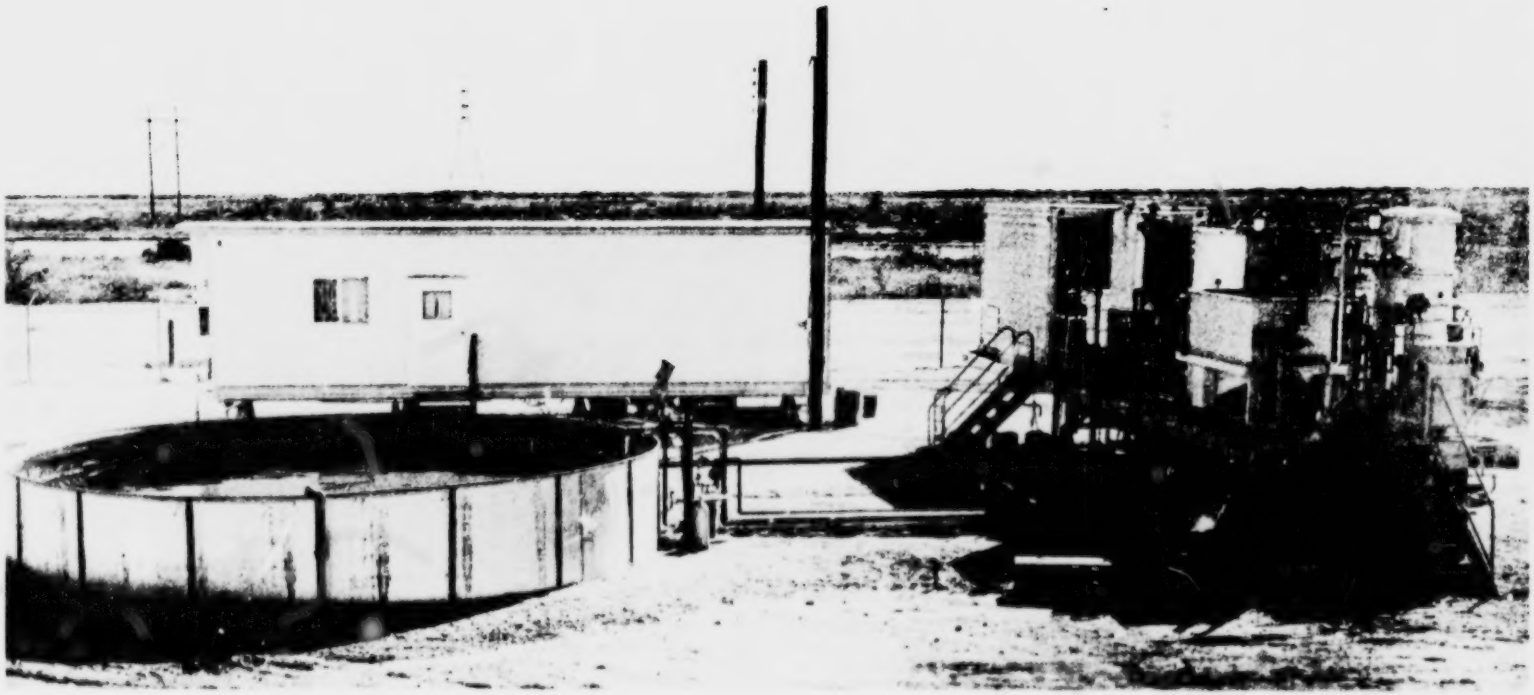

Figure VI-1. Odessa Waste Water Demonstration Unit

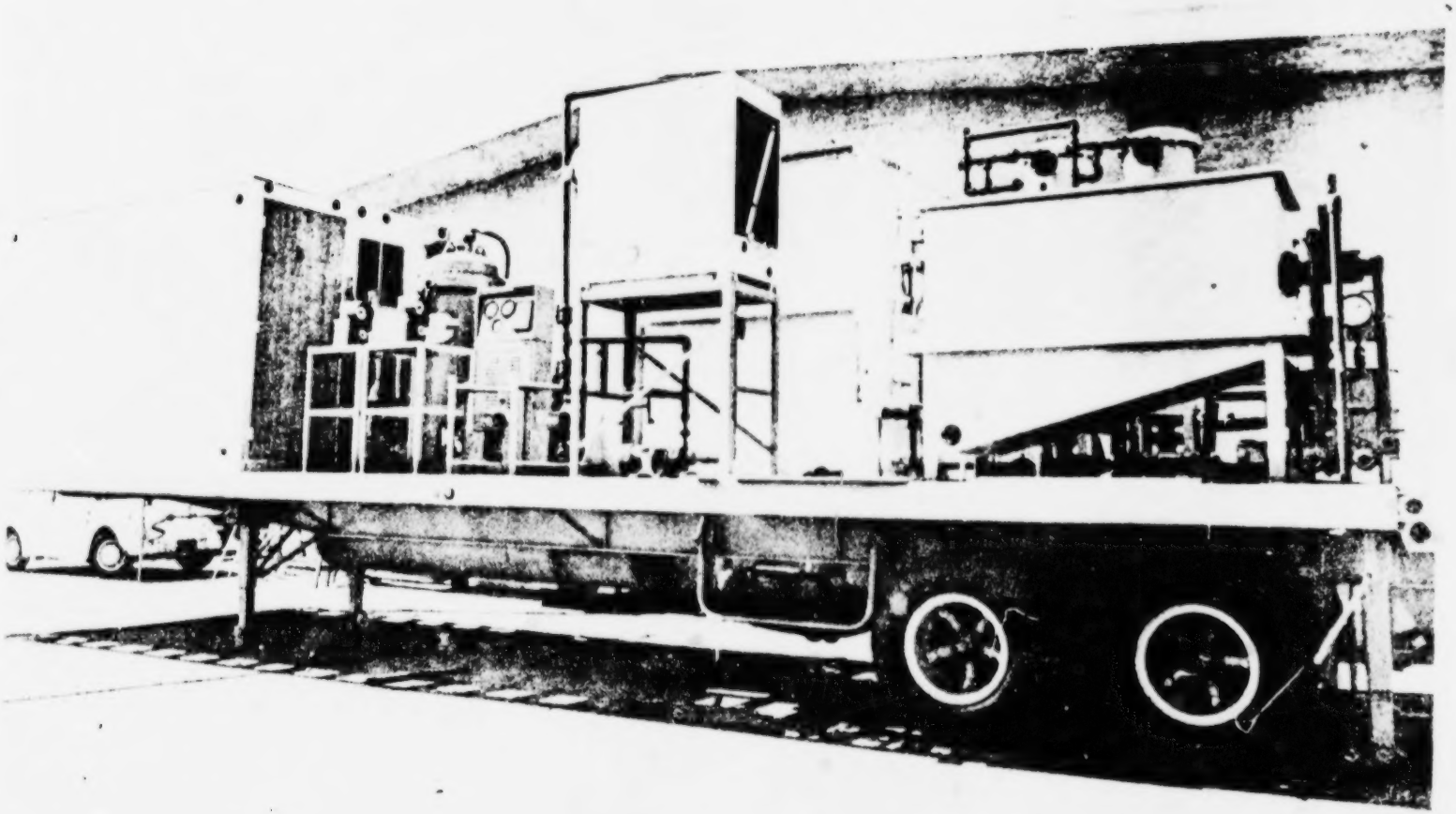

Figure VI-2. Pretreatment Trailer and Reverse Osmosis Unit

Figure VI-3. Bench Scale Facilities and Control Laboratory

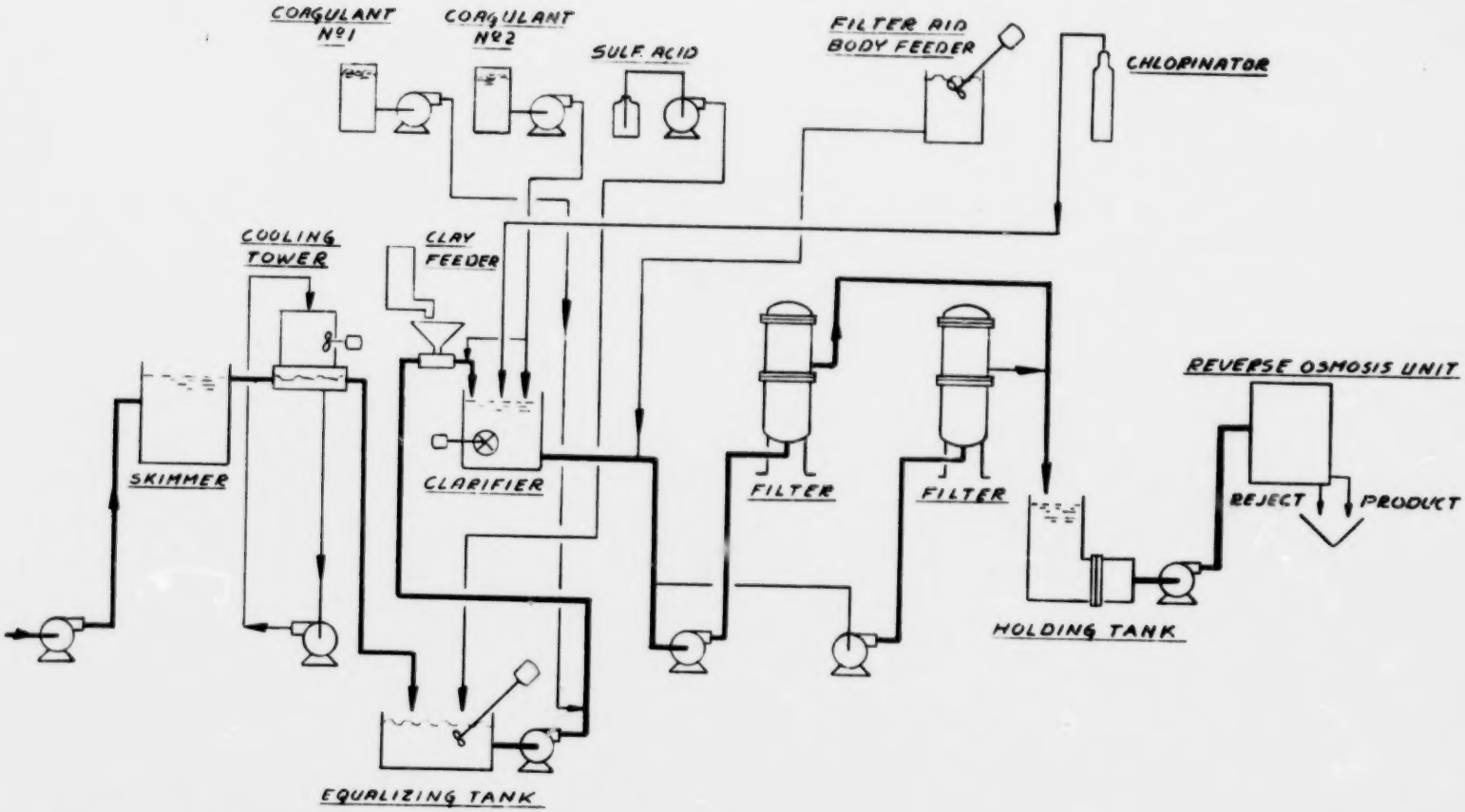

Figure VI-4. Odessa Waste Water Demonstration Unit - Simplified Flow Diagram

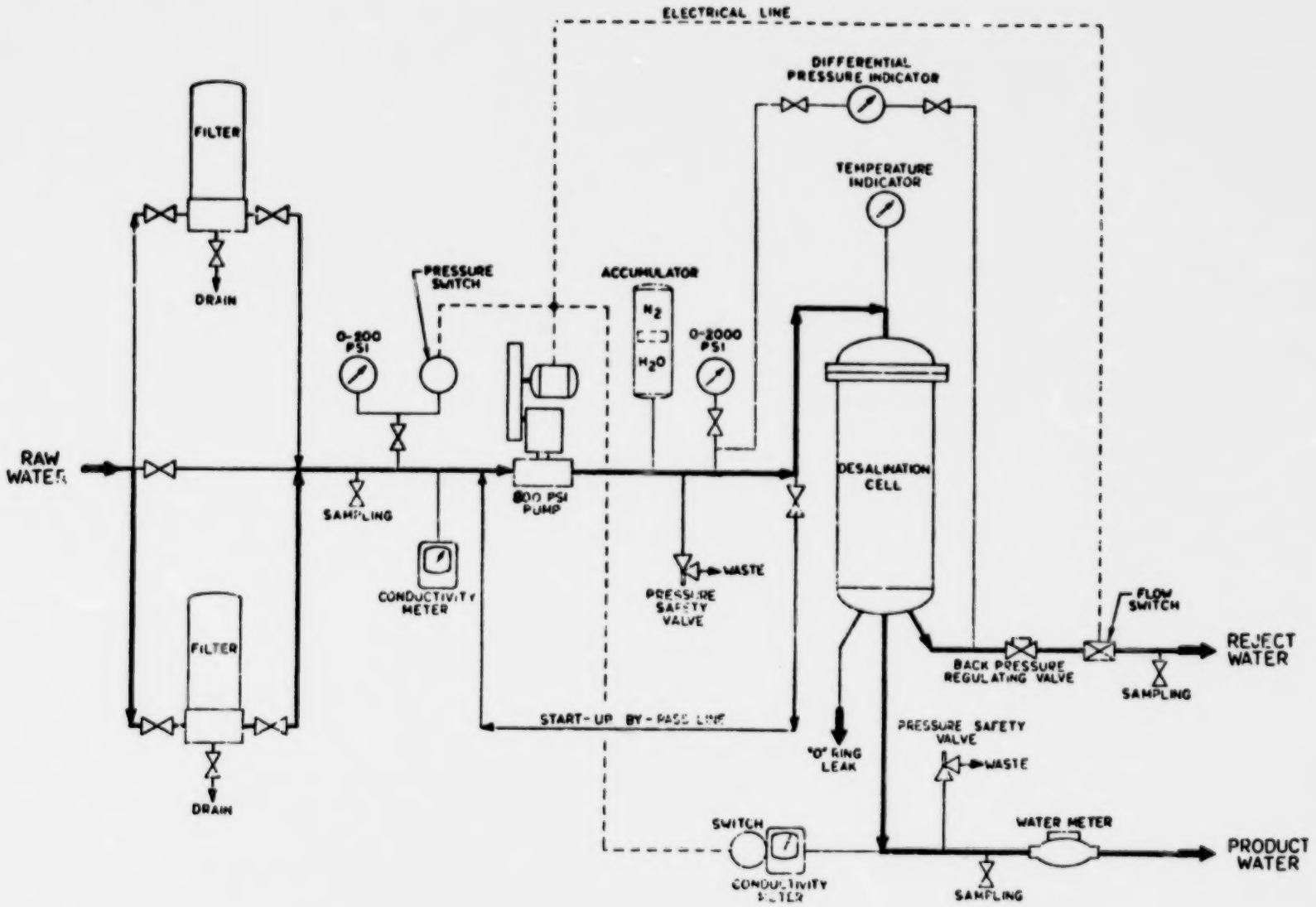

Figure VI-5. Reverse Osmosis Unit - Simplified Flow Diagram

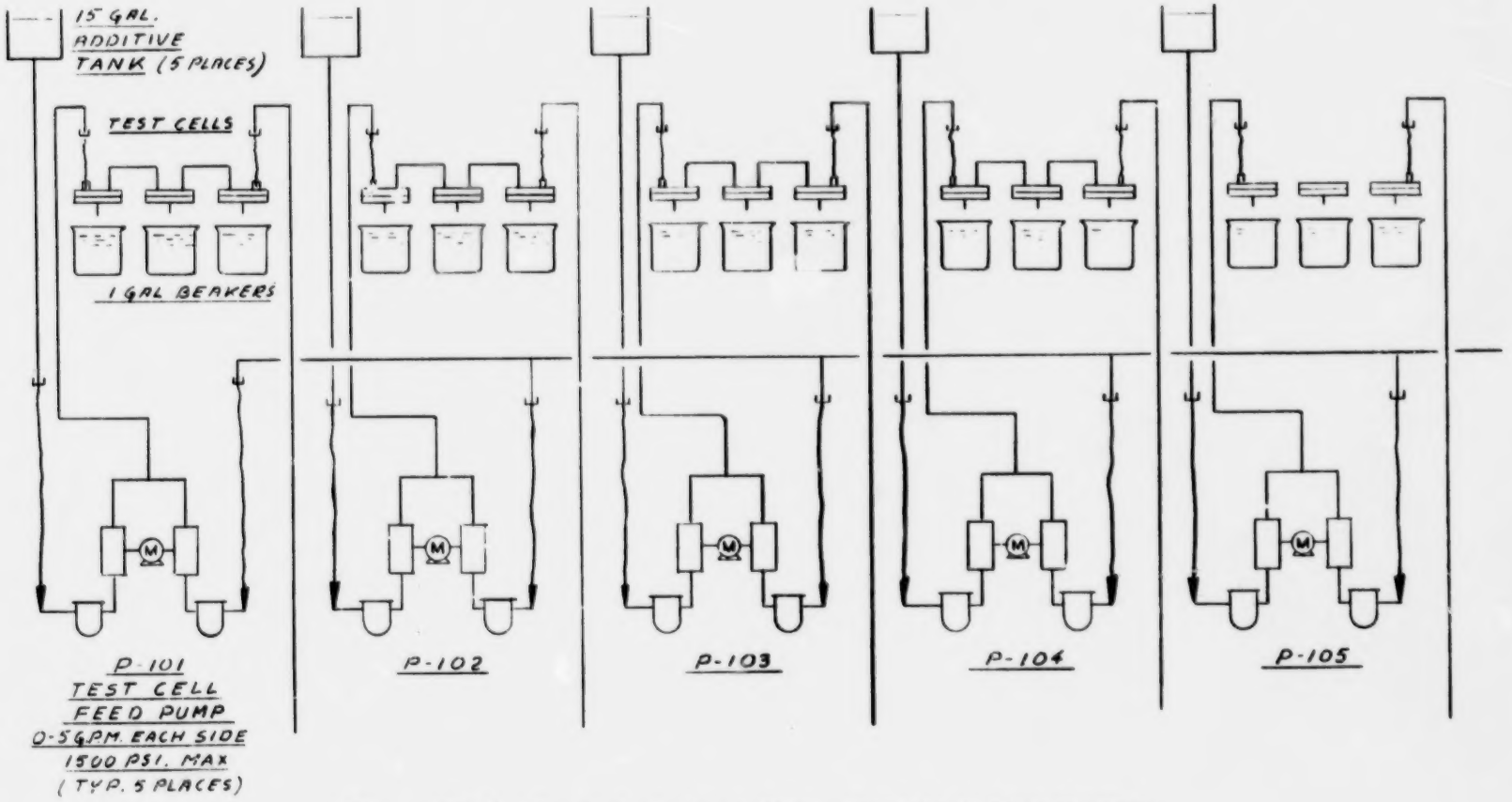

Figure VI-6. Bench-Scale Test Unit - Smplified Flow Diagram

VII. ANALYTICAL FACILITIES AND PROCEDURES

Analytical facility and procedure modifications made during this report period are described below.

A. FACILITIES

The Wallace & Tiernan Model A790 Amperometric Titrater, ordered during the last report period, was received and put into use. The unit functions well and greatly reduce the operator time required for running chlorine analyses. A laboratory balance was also purchased for weighing reagents used in flocculation jar tests.

B. PROCEDURES

1. Estimates of Total Dissolved Salts

Five R-O product water samples were analyzed by Pomeroy, Johnston and Bailey (see Appendix E) to determine the relationship between dissolved salts and conductivity. The analyses show that the ratio of dissolved salts (me/l) to conductivity (mmhos) is about 0.0088. Previous analyses indicated that the ratio for feed waters is about 0.01. Multiplying these ratios by 58.5, (the molecular weight of sodium chloride) the ratios for dissolved salts, expressed as ppm sodium chloride, to conductivity (mmhos) are obtained. The ratios are 0.515 for R-O product waters and 0.585 for feed waters. These ratios have been used for estimating membrane permeation ratios for both the demonstration R-O unit and the bench-scale units.

2. Iron Analyses

The Hach phenanthroline method for iron analyses has been shown to be unsatisfactory. Various organics in the Odessa feed waters interfere with the test, causing erratic results. Samples were sent to Pomeroy, Johnston and Bailey for analyses; the results of these analyses were also erratic (see Appendix F). Future iron analyses will be made using perchloric acid digestion and isopropyl ether extraction, for removal of interfering organics, followed by the orthophenanthroline color test for iron. This method was recommended by Dr. Richard Pomeroy, of Pomeroy, Johnston and Bailey. Since the field laboratory is not equipped for this type of analytical work, iron analyses will be run by a commercial laboratory.

VIII. DATA ACQUISITION PLAN

A preliminary acquisition plan, for collection of data from the Odessa Demonstration Run, was first prepared on June 7, 1967 (see Reference 1b, Appendix E) and was submitted to FWPCA for approval. Many suggestions for improving the plan were then offered by FWPCA, and a revised plan was then prepared and submitted (see Reference 1c, Section VI). As a result of operating experience gained at Odessa, and of further suggestions offered by Mr. Jack Witherow of FWPCA and by Dr. Richard Pomeroy of Pomeroy, Johnston and Bailey, the data acquisition plan has again been revised and is included as Table VIII-1 of this report.

TABLE VIII-1

DATA ACQUISITION PLAN FOR DEMONSTRATION OF INDUSTRIAL WATER RENOVATION PLANT AT ODESSA, TEXAS

Sheet 1

-PLANT OPERATION-

Item	Measured Variable	Purpose of Record	Recording Method	Recording Point											
				Skimmer Feed	Cooling Tower Feed	Equalizer Tank	Clarifier Feed	DE Filter Feed	Reverse Osmosis Feed	Reverse Osmosis Reject	Reverse Osmosis Product	Test Cells Feed	Test Cells Product	Other
1	Pressure	Plant Operation	Gage & Recorder						C			2D		D (R.O. unit pump suction
2	Differential Pressure	Plant Operation	Gage					2D*		D*				
3	Temperature	Plant Operation	Gage		C				D					
4	pH	pH Control	Meter		C		C							
5	Flow Rates	Flux & Recovery	Meter & Volumetric Measurement						DX	D	D	DX	D	D Test Cell Reject
6	Conductivity	Plant Operation	Meter	C					C		C			
7	Coagulant Consumption	Chemical Demand & Usage												
	#1		Volume				D							
	#2		Volume				D							
	#3		Weight				AR							
8	Filter Aid Consumption	Chemical Usage	Volume					D						
9	Acid Consumption	Chemical Usage	Volume			AP								D
10	Chlorine Consumption	Chemical Usage	Weight											W
11	Filter Cartridge Consumption	Expendable Supplies	Number Used											AR
12	Floatables from Skimmer	Quantitate Waste	Volume											D

[a] C denotes continuous recording; D, daily; 2D, twice daily; AR, as required; X Calculation from other data; W, Weekly.

[b] Three-cell test unit parallel to demonstration RD unit.

* Differential pressure readings are taken across the D. F. filter and from feed to reject stream on the R. O. cell

TABLE VIII-1 (cont.)

-PLANT OPERATION-

Item	Measured Variable	Purpose of Record	Recording Method	Recording Point									
				Skimmer Feed	Cooling Tower Feed	Equalizer Tank	Clarifier Feed	DE Filter Feed	Reverse Osmosis Feed	Reverse Osmosis Reject	Reverse Osmosis Product	Test Cells[b] Feed Product	Other
13	Settled Sludge from Skimmer	Quantitate Waste	Volume										D
14	Sludge from Clarifier	Quantitate Waste	Volume										D
15	Filter Backwash	Quantitate Washwater	Calculated Volume per Backwash										D
16	Downtime	Plant Operation											AR
17	Electric Power Consumption	Power Requirements											
	Total		Meter										W
	Support Van.		Daily										W
	Demonstration		Daily										W
													W
18	Maintenance Routine	Maintenance Requirements	a. Man Hours b. Material $										AR
19	Maintenance Non-routine	Maintenance Requirements	a. Man Hours b. Material $										AR

[a] C denotes continuous recording; D, daily; 2D; twice daily; AR, as required; X Calculation from other data; W, Weekly.

[b] Three-cell test unit parallel to demonstration RD unit.

• Differential pressure readings are taken across the D. E. filter and from feed to reject stream on the R. O. cell

TABLE VIII-1 (cont.)

-ANALYSES-

Item	Measured Variable	Purpose of Test	Test Method	Sampling Point[a]											
				Skimmer Feed	Cooling Tower Feed	Equalizer Feed	Clarifier Feed	DE Filter Feed	Reverse Osmosis Feed	Reverse Osmosis Reject	Reverse Osmosis Product	Test Cells[b] Feed	Test Cells[b] Product	Other
20	Turbidity	Plant Operation	Hach Turbidimeter	SDG	SDG		SDG	SDG	SDG		SDG			
21	Settleable Solids	Plant Operation	Imhoff Cone	SDG	SDG		SDG	SDG*	DG*					
22	Conductivity	TDI Determination & Instrument Check	Cond. Bridge	SDG					SDG	SDG	SDG	SDC	SDC	
23	pH	Solubility Computation	Lab. pH Meter	SDG					SDG	SDG	SDG			
24	Total Alkalinity	Solubility Computation	Hach Titration	SDG					SDG		SDG			
25	Calcium	Scaling	Hach EDTA	SDG					SDG	SDC	SDG			
26	Total Hardness	Scaling	Hach	WC					WC		WC			
27	Bicarbonate	Scaling	Calculate from 23, 24, 25 and 26	SDX					SDX		SDX			
28	Sulfate	Scaling	Hach Turbidimeter	WG					WG	WG	WG			
29	Iron	Membrane Deposits	Modified Orthophenanthroline	WC					WC		WC			
30	Manganese	Membrane Deposits	Hach Periodate Ox.	WC					WC		WC			
31	Total Organic Carbon	Water Quality Criteria	Carbon Analyzer	WC					WC		WC			
32	Total Dissolved Inorganics	Water Quality Criteria	Calculate from 6	WX					SDX		SDX		SDX	
33	Residual Chlorine	Plant Operation	Amperometric Titration						SDG	SDG	SDG		SDG	

TABLE VIII-1 (cont.)

-ANALYSES-

Item	Measured Variable	Purpose of Test	Test Method	Sampling Point[a]										
				Skimmer Feed	Cooling Tower Feed	Equalizer Feed	Clarifier Feed	DE Filter Feed	Reverse Osmosis Feed	Reverse Osmosis Reject	Reverse Osmosis Product	Test Cells[b] Feed	Test Cells[b] Product	Other
34	Coliforms	Water Quality Criteria	Hach Presumptive	WG					WG		WG			
35	Organic Nitrogen	Water Quality Criteria	Stand. Methods	WC					WC		WC			
36	Ammonia	Water Quality Criteria	Stand. Methods	WC					WC		WC			
37	Nitrate + Nitrite	Water Quality Criteria	Stand. Methods	WC					WC		WC			
38	Total Nitrogen	Water Quality Criteria	Calculate from 35, 36 and 37	WX					WX		WX			
39	Total Phosphate	Water Quality Criteria	Hach Ortho & Meta	WC					WC		WC			
40	Chloride	Water Quality Criteria	Hach Mercuric Nitrate	WC					WC		WC			
41	Color	Water Quality Criteria	Hach Colorimeter	WG					WG		WG			
42	Detergents	Water Quality Criteria	Methyl Green	MC*					MC*		MC*			
43	Phenol	Water Quality Criteria	APHA 4 Amine antipyrene	MSDC*					MSDC*		MSDC*			
44	Isopropyl Alcohol	Water Quality Criteria	Gas Chromatography	MC*					MC*		MC*			
45	Butadiene	Water Quality Criteria	Gas Chromatography	MC*					MC*		MC*			
46	Styrene	Water Quality Criteria	Gas Chromatography	MC*					MC*		MC*			

NOMENCLATURE

SD=Samples taken Mon., Wed. & Fri.
W=Weekly
M=Monthly
C=Composite Sample
G=Grade Sample
X=Calculation
MSDC=Analysis run once per month on SD Composite Sample

* These tests will be discontinued if initial results show no significant quantity.

REFERENCE

1. Demonstration of Industrial Water Renovation Plant at Odessa, Texas, an Aetron report to United States Department of Interior, Federal Water Pollution Control Administration, Grant No. WPRD 31-01-67.

   a. Progress Report No. 1, 30 April 1967.

   b. Progress Report No. 2, July 1967.

   c. Progress Report No. 3, September 1967.

APPENDIX A

CORRECTION METHODS FOR REVERSE-OSMOSIS PROPERTIES

I. CORRECTED MEMBRANE FLUX

Membrane flux, J, can be adjusted to various conditions of operating pressure, P; feed concentration, C; recovery rate, R; osmotic constant, α; and average boundary layer modulus, $(\overline{C_w}/C_o)$ by use of Equation (A-1), below:

$$J_s = J_1 \left[f(T)\right] \left(\frac{P_s}{P_1}\right) \frac{\left[1 - \left(\frac{\overline{C_w}}{C_o}\right)_s C_s \left[f(R_s)\right] \frac{\alpha_s}{P_s}\right]}{\left[1 - \left(\frac{\overline{C_w}}{C_o}\right)_1 C_1 \left[f(R_1)\right] \frac{\alpha_1}{P_1}\right]} \qquad \text{(A-1)}$$

where

$$f(R) = \frac{1}{R} \ln \frac{1}{1-R}$$

$$\alpha = 0.0114 \frac{\left[T(^\circ F) + 460\right]}{537} \frac{\text{psi}}{\text{ppm}}$$

$$\left(\frac{\overline{C_w}}{C_o}\right) = 1 + \frac{0.60\ J}{20\ \text{gfd}}$$

$$\left[f(T)\right] = \frac{1}{1 + 0.0166\ (T - 77^\circ F)}$$

The subscript, s, in Equation (A-1) denotes a standard condition, in this case $T_s = 77^\circ F$, $P_s = 500$ psi, $C_s = 5000$ ppm, $R_s = 0.70$, and $\alpha_s = 0.0114$ psi/ppm. The subscript, 1, denotes another set of conditions under which data are available. Table A-1 gives the values of the variables substituted in Equation (A-1) for the three sets of data in Table II-2.

TABLE A-1

Test	J_1 gfd	P_1 psi	$\left(\frac{\overline{C_w}}{\overline{C_o}}\right)_1$	C_s ppm	$f(R_1)$	α_1 psi/ppm	$f(T)$	$\left(\frac{\overline{C_w}}{\overline{C_o}}\right)_s$	$f(R_s)$
Odessa No. 1	18.5	600	1.55	5,340	1.91	0.0112	1.13	1.52 (J_s = 17.3)	1.72
Odessa No. 2	12.8	430	1.38	5,380	1.43	0.0112	1.13	1.49 (J_s = 16.4)	1.72
P-S Test	16.5	420	1.51	4,887	1.36	0.0116	0.86	1.49 (J_s = 16.6)	1.72

The corrected membrane fluxes as calculated from Equation (1) were 17.3, 16.4, and 16.6 gfd, respectively, for the three tests.

II. CORRECTED PERMEATION

Membrane permeation, P_e, can also be adjusted to a set of normal conditions (pressure, temperature, recovery and feed concentration) and at the corrected flux (see paragraph I). The permeation is corrected by using Equation (A-2) below:

$$P_s = P_1 \left[f'(T)\right] \frac{J_1}{J_s} \frac{\left[\left(\frac{C_w}{C_o}\right)_s \left[f(R_s)\right] - P_s\right]}{\left[\left(\frac{C_w}{C_o}\right)_1 \left[f(R_1)\right] - P_1\right]} \qquad \text{(A-2)}$$

where

$$\left[f'(T)\right] = \frac{1}{1 + 0.0025\ (T - 77^{\circ}F)}$$

The values determined for P_s, using Equation (A-2), were 21.9, 23.9, and 25.3%, respectively, for the three test conditions.

APPENDIX B

WASTE WATER DEMONSTRATION UNIT AT ODESSA, TEXAS
PRE-TREATMENT TESTS
START-UP PROCEDURE

Revised 9/27/67

PRELIMINARY PREPARATIONS

1. Set the skimmer feed pumps (P-1) delivery rate to 11.5 ± 0.5 gpm. Also set the equalizer tank discharge pump (P-5) at 11.0 ± 0.5 gpm. Throttle discharge valves to set rate. P-5 flow should be directed through the jet eductor.

2. Install slow-speed belt drive pulleys (1 5/8" O.D. pulleys on motors and 5" O.D. pulleys on gear box) on all additives' pumps P-3, P-4, P-7, P-8, and FA-1. Check pump delivery rate at 10% and 100% stroke. Draw calibration curve.

3. With P-1 set as in Step 1, above, fill the skimmer, cooling tower basin, and equalizer tank.

4. Start flow through the pH transmitters and check readings of both pH analyzers against the laboratory pH meter. Put the pH recorder in service (see instruction manual). Adjust pH recorder if necessary so that the pens read the same as pH meter (adjustment is made by adjusting output signal of analyzer). Label recorder for easy identification of pens and ranges.

PRELIMINARY PREPARATIONS (cont'd)

5. Put conductivity recorder in service (see instruction manual). Check performance of conductivity meter (CM-3) on skimmer inlet against laboratory conductivity meter. Calibrate pH meter if necessary. Check recorder against pH meter readings, calibrate recorder if necessary. Label recorder and meters for easy identification of pens and ranges.

6. Put temperature recorder in operation. Check recorder readings against thermometer readings of skimmer and cooling tower effluents. Calibrate recorder if necessary (see instruction manual).

7. Install a carboy of concentrated sulfuric acid. Put acid pump (P-3) into operation - set on automatic and 50% stroke. Monitor pH of equalizing tank effluent and check the operation of the pH controller. Controller should be set to shut off acid pump at pH 7.5.

8. Shut off acid feed and let pH rise. Check the operation of the pH alarm. Alarm should sound at a pH valve, on equalizing tank effluent, of 8.0. Reset alarm set point if necessary.

CLARIFIER START-UP

9. Fill T-7 with an alum solution prepared as follows: add 10.4 lbs. of alum to a half-full calibrated 8-gallon bucket. Mix thoroughly until

CLARIFIER START-UP (cont'd)

9. fully dissolved. Add water to bring level to 5 gallons. Use filtered feed water for making up the batch (the laboratory D.E. filter can be used for the initial batch).

10. Mount the portable agitator from FA-1 on T-8.

11. Fill T-8 with a Separan NP10 solution prepared as in Step 8, except add 37.8 grams Separan NP10 to a 5-gallon batch. (Do not add alum to T-8 batches.) Since Separan NP10 goes into solution slowly, it may not be practical to fully dissolve the powder in the buckets. Continue agitation in T-8 for about 2 hours, or until all translucent particles are fully dissolved.

12. Fill the syntron feeder (DF-1) with bentonite clay (Aquagel) and calibrate feeder to deliver as close as possible to 2.08 gm/min. (This is equivalent to 50 ppm.)

13. Start flow from P-5 to the clarifier at 11 gpm. Direct flow through the jet eductor on the feed line. Start clarifier agitator. Close 2" drain line and sample valves from coagulation zone.

CLARIFIER START-UP (cont'd)

14. Direct the alum solution from T-7 to P-5 discharge. Start the alum pump and adjust stroke to 15%. (The pump should deliver 0.4 gph at 15% stroke. This is equivalent to 150 ppm alum.)

15. Direct the Separan solution from T-8 to the mixing pot on the clarifier inlet. Start the Separan pump and set the stroke to 12.5%. (The pump should deliver 0.33 gph at 12.5% stroke. This is equivalent to 1 ppm Separan.)

16. Make sure the jet eductor funnel is clean and dry. Start solids feeder DF-1. Check delivery rate of unit. Adjust if necessary to come as close as possible to 2.08 gm/min.

17. Leave the 2" drain valve from the clarifier clear-well open until a sludge blanket has been formed and the water from the clarifier is reasonably free from heavy floc. Run periodic turbidity readings on clarifier product during this period. Make a plot of turbidity vs. time.

18. After clarifier product is acceptable, close clear-well drain. Check operation of level switch as level rises. Valve EOV-1 on the pre-treated water storage tank should open when the water level reaches

CLARIFIER START-UP (cont'd)

18. the level probe. Check the capacity of the clarifier overflow when clarifier is full. Overflow should handle full 11 gpm feed rate.

19. Re-check pumping rate of P-5 by measuring clarifier overflow back to the equalizing tank. Pump rate should be 11.0 ± 0.5 gpm.

D. E. FILTER START-UP

20. Fill the D.E. slurry tank with filtered water from the laboratory D.E. filter (on subsequent batches the fill line from P-9 can be used). Calibrate the tank as it is being filled. Install and start the agitator, and add 0.417 # of Johns-Manville Celite 512 for each gallon of water. Keep agitator running (this is a 5% slurry).

21. Prepare a pre-coat slurry by mixing 5 lbs. of Johns-Manville Celite 512 in 5 gallons of water. Make sure the 3" drain valve on filter F-1 is closed, and dump the pre-coat into the funnel on F-1 feed line. This corresponds to a pre-coat of 0.1 lb/sq. ft.

22. Start flow recirculating through filter F-1. Continue to circulate until the water in F-1 (look through site glass) is clear, and samples taken from the sample valve on P-6A discharge are clear.

D. E. FILTER START-UP (cont'd)

23. Close 3-way valve on filter F-1 effluent, to flow in either direction. Check operation of automatic bypass flow regulator, FRR-1. Flow regulator should circulate enough water to maintain the filter cake in place. This can be observed through the site glasses in filter F-1.

24. Divert filter F-1 effluent to pre-treater water storage tank and start D.E. body feed to F-1.

25. Take initial filter effluent sample for turbidity measurement. Periodically take samples of filter effluent and plot turbidity vs. time for one filter cycle.

26. As soon as the level in T-1 is high enough to prime pump P-9 connect two hoses (two hoses are needed for capacity) from P-9 discharge to waste disposal line. Close filter feed valves on R.O. unit. Calibrate P-9 discharge rate to 10 $\pm$0.5 gpm, to simulate R.O. unit feed.

27. Check operation of D.E. body feed unit FA-1, and solenoid diverter valve EOV-2. Label control switch to indicate which position feeds which filter. Direct flow to filter F-1. Set feed pump stroke while running at 50%. Set flush cycle time at 50%. These settings are

D. E. FILTER START-UP (cont'd)

27. roughly equivalent to 40 ppm. Tank level should drop at rate of 0.31 inches/hour. Check pump delivery rate and make additional stroke adjustments if necessary. Set D.E. pump control on "auto".

28. Purge debris from 1/2" flushing line to D.E. body feed unit FA-1, and open valve on flushing line. Check operation of flushing unit. Flushing valve should open for 2 1/2 minutes at intervals of 5 minutes.

29. As the pre-treated water storage tank fills, check level control operation. When the level reaches the top probe, solenoid valve EOV-1 (on pre-treated water storage tank unit) should close, the D.E. body feed pump should stop.

30. Check the operation of the differential pressure gauge on filter F-1. The check should include the following:

    a. Zero-point adjustment.

    b. Alarm-point setting. The alarm should sound at 35 psi differential. (See manufacturer's manual for detailed instructions.

D. E. FILTER START-UP (cont'd)

31. Repeat Steps 17, 18, 19, and 27 on filter F-2. This will put filter F-2 stand-by.

SIMULATED R. O. UNIT START-UP

32. Plug off product outlet at bottom of R. O. cell.

33. Perform the Fill procedure and Inital Start-up procedure as described in R. O. manual except for Steps M, N, and O. Shut off P-9 discharge flow to waste when R. O. unit pump is operating. Set back pressure regulator to 750 psig (750 psi selected to test mechanical operation of R. O. unit).

34. Check feed pump delivery rate by measuring reject stream flow rate. Flow rate should be approximately 10 gpm. Record actual flow rate.

35. Check operation of pressure recorder on main instrument panel, and check conductivity meter reading against laboratory conductivity measurement on R. O. unit feed.

CHLORINATOR START-UP

36. Check all chlorine lines to make sure all connections and diffusers are

CHLORINATOR START-UP

36. properly installed. Check solenoid valve to make sure valve is open (valve should be open unless the clarifier clear-well level is too low or the pre-treated water storage tank level is too high).

37. Direct the flow from chlorinator CF-2 to the pre-treated water storage tank.

38. Perform the complete Start-up procedure on chlorinator CF-2, as described on Pages 363-5 and 363-6 of the Wallace and Tiernan chlorinator instruction book. Set chlorinator flow at 0.6 lbs/day. This is equivalent to a chlorine feed of 5 ppm. Record initial cylinder weight.

39. Allow several hours for the effects of the chlorination to reach equilibrium. Take samples of the water flow into T-1, the R.O. unit feed, and the R.O. unit reject water. Test samples for coliform (presumptive test only) and chlorine residual. Adjust chlorine feed rate if necessary, to maintain at least 0.1 ppm chlorine in R.O. reject stream.

40. If the coliform tests are positive for either the R.O. unit feed or the reject stream, direct the flow from chlorinator CF-1 to the clarifier discharge and repeat Steps 35 and 36.

CHECK COOLING TOWER OPERATION

41. Direct flow from pump P-2 to circulate through cooling tower. Start pump.

42. Set cooling tower fan control on "auto". Check fan control set point. Fan should operate above 80°F., and stop when temperature falls below 80°F.

SAMPLE COLLECTION

43. Obtain three 5-gallon bottles for composite sample collection.

44. Check operation of sample timer and solenoid valves at all three composite sample points - skimmer inlet, R.O. feed, and R.O. product (actual collection of R.O. product samples can be taken only after membrane stack is installed). Timer should open solenoid valve once each hour for about 5 seconds. Volume collected per hour should be about 360 ml. (2.3 gal/24 hours).

45. Charge each 5-gallon composite sample bottle with 9 ml. concentrated sulfuric acid for 24-hour composite, or 18 ml. for 48-hour composite before collecting sample.

SAMPLE COLLECTION (cont'd)

46. Collect 400 ml. daily, or 800 ml. every two days from each composite. Mix the contents of each composite thoroughly. Discard the balance of the composite samples. By this method, a weekly composite sample of 2800 ml. from each composite sampling point can be collected.

47. Collect 1-gallon grab samples from each of the following sample points on Mondays, Wednesdays, and Fridays.

Skimmer feed

Cooling tower feed

Clarifier feed (before coagulant addition)

D.E. filter feed

R.O. unit feed

R.O. unit reject

R.O. unit product (after membrane stack is installed).

APPENDIX C

MEMBRANE FLUSHING TESTS
BENCH-SCALE TEST NO. 2
TEST PLAN

I. TEST OBJECTIVES

A. Determine whether the water obtained from the demonstration pre-treatment unit is detrimental to membranes.

B. Determine whether periodic flushing of the membrane surfaces at low pressures, with water, significantly improves membrane performance.

C. Determine whether the addition of air to the water flush improves the efficiency of the flush.

D. Determine the frequency of flushing required.

II. TEST PREPARATIONS

A. Connect a hose from P-9 discharge to the 1/2-in. plastic feed line in the bench-scale unit. This water will be used for all feeds, and for flushing. Prepare adapter for connecting P-9 discharge hose to one of the stainless steel feed lines in addition to the 1/2-in. plastic line.

B. Set pumps 1A, 2A, 3A, 4A, and 5A at zero stroke and close valves on pump discharge. Set pumps 1B, 2B, 3B, 4B, and 5B to 5 $\pm$ 0.25 gpm and connect to the plastic feed line.

C. Set back-pressure regulators on all units at 600 psi.

D. Install a temporary air line and pressure regulator to deliver air at 25 psi to the discharge sample valves on pumps 1B and 2B. Install pressure relief valve, set at 50 psi, on the air supply line.

E. Install the quick-disconnect flexible hose connections (the ones now used on pumps 1A, 2A, 4A, and 5A suction) to the discharge sample valves on pumps 1A, 2A, 4A, and 5A. These will be used for flushing, and will be connected to the 1/2-in. PVC line.

F. Connect the suction lines from pumps 1B, 2B, 3B, 4B, and 5B to the stainless steel line, supplied by pump P-9 discharge.

G. The pretreatment unit must be in operation and producing good quality pretreated water, i.e., turbidity less than 0.5 JTU and pH 7.0 $\pm$ 0.5. The feed water should be chlorinated to a minimum residual of 0.5 ppm at the test cell feed.

H. Run millipore acceptance test on representative samples of clarifier effluent and D.E. filter effluent. Compare with acceptance criteria set by El Paso Products and previous test results (see "Procedure for Running Millipore Acceptance Test on Feed Water", 8/23/67).

I. Install membranes in all 15 cells. Check initial membrance performance. Replace any defective membranes.

III. OPERATION

Operate all units on P-9 discharge (R-O feed water) at 600 psi with the following flushing schedule.

Unit No. 1

Water and air flush for 5 minutes once every 24 hours.

Unit No. 2

Water and air flush for 5 minutes once every 12 hours.

Unit No. 3

No flush

Unit No. 4

Water flush only for 5 minutes once every 12 hours.

Appendix C (cont.)

Unit No. 5

Water flush only for 5 minutes once every 24 hours.

IV. DATA COLLECTION

Feed water - Record pH, conductivity, TDI, temperature, and residual chlorine daily.

Product - Record conductivity, flux rates, TDI, and permeation daily.

Reject Stream - Record residual chlorine daily.

V. TEST DURATION

The initial test is scheduled for seven consecutive days. The test may be extended if the results in 7 days are inconclusive.

APPENDIX D

FLOCCULATION
JAR TEST NO. 1

Date: 9-20-67 1400-1600 Hrs.

Objectives: Find coagulation formulation with faster settling time than previously used, i.e., 150 ppm Alum and 1 ppm Separan NP10.

100 rpm's for 2 min
50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 15 min

Feedwater:
pH 7.5
Turbidity 3

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	0	50	0	100	0	150
(mg/700 ml)	0	35	0	70	0	105
Alum	150	150	200	150	250	150
(mg/700 ml)	105	105	140	105	175	105
Separan NP10	1	1	1	1	1	1
(ml stock sol.*/700 ml)	.7	.7	.7	.7	.7	.7
Turbidity JTU	2.5	2	2	2	2	1
pH	6.0	6.4	6.4	5.9	5.6	6.45
Settling Time (min)	9	4	7-1/2	6	11	5
Floatables 2 min final	3	1	3	1	3	1
Floc Appearance	3	3	3	3	3	3

Comments: Floc observations were made after initial two minutes of mixing and before the agitator was stopped to allow settling. Floc formation were rated as follows: 3 very uniform, 2 fairly uniform, 1 not very uniform.

*Stock solution - 1 part Separan NP10 to 1000 parts water. Jars with bentonite clay added had faster settling times.

FLOCCULATION
JAR TEST NO. 2

Date: 9-28-67 1500-1700 Hrs.

Objectives: To test effectiveness of Diatomaceous earth filter aids as flocculation weighting agents. Anticipation of using the D.E. Filter backwash sludge as a substitute for Bentonite clay.

100 rpm's for 3 min
50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 15 min

Feedwater:
pH 7.5
Turbidity 40

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	0	0	50	50	0	0
(mg/700 ml)	0	0	35	35	0	0
Alum	150	150	150	150	150	150
(mg/700 ml)	105	105	105	105	105	105
Separan NP10	1	1	1	1	1	1
	.7	.7	.7	.7	.7	.7
Hyflo JM Supercell	0	0	0	0	50	50
	0	0	0	0	35	35
Turbidity JTU	3.3	3.4	3.8	2.75	2.6	2.7
pH	6.7	6.7	6.7	6.75	6.65	6.7
Settling Time (min)	5-1/2	5-1/2	5-1/2	3-1/2	3-1/2	2-1/2
Floatables						
Floc Appearance	Very Uniform	VU	VU	VU	VU	VU

Comments: Floc observations were made after 2 minutes of mixing and before agitator was stopped to allow settling. Floc was found to be the same at both times. Samples using JM Hyflo Supercell as weighting agent settled faster and had lower turbidities than samples using bentonite clay.

FLOCCULATION
JAR TEST NO. 3

Date: 9-28-67 14-16 Hrs.

Objectives: Test equal parts of Alum in all jars with 2 jars containing no weighting agent; 2 containing Bentonite clay; 2 with Filter cell diatomaceous earth and Separan NP10 to be used in all jars as a control.

100 rpm's for 2 min
50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.2
Turbidity 24

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	0	0	50	50	0	0
Alum	150	150	150	150	150	150
Separan NP10	1	1	1	1	1	1
JM "Filtercell"	0	0	0	0	50	50
Turbidity JTU	3.6	3.6	2.0	2.2	1.75	1.5
pH	5.9	6.05	6.05	5.95	6.1	6.05
Settling Time (min)	2	2	1-1/2	1-1/2	1	1
Floatables	Very Uniform	VU	VU	VU	VU	VU

Floc Appearance

Comments: More fine floc on Jars A & B. This test had larger floc on all jars than Test 2. Samples using filter-cel as weighting agent settled faster, and had lower turbidities than samples using bentonite clay.

FLOCCULATION
JAR TEST NO. 4

Date: 10-17-67

Objectives: To test the effectiveness of Separan NP10 and Filtercell to reduce product turbidities.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	150	150	150	150
Filtercell	0	0	50	50	50	50
Separan NP10	0	0	0	0	1	1
Turbidity JTU	5.7	7.0	8.8	12.0	7.2	6.3
pH						
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: 1 ppm of Separan NP10 is only moderately beneficial. In samples without Separan NP10 the diatomite (Filtercel) produces somewhat higher turbidities samples with Separan. This does not indicate that the plant clarifier would work better without diatomite, because the increased density of the sludge blanket may be more important.

FLOCCULATION
JAR TEST NO. 5

Date: 10-17-67

Objectives: To test the effectiveness of Separan NP10 and Filtercell to reduce product turbidities.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater: [redacted]
pH 5.1
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	150	150	150	150
Filtercell	50	50	0	0	50	50
Separan NP10	1	1	0	0	0	0
Turbidity JTU	4.4	4.4	5.8	4.7	5.0	4.9
pH						
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: 1 ppm of Separan NP10 is only moderately beneficial. In samples without Separan NP10 the diatomite (Filtercel) produces somewhat higher turbidities samples with Separan. This does not indicate that the plant clarifier would work better without diatomite, because the increased density of the sludge blanket may be more important.

FLOCCULATION
JAR TEST NO. 6

Date 10-17-67

Objectives: To test the effectiveness of Separan NP10 and Filtercell to reduce product turbidities.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 5.3
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	150	150	150	150
Filtercel	50	50	50	50	0	0
Separan	0	0	1	1	0	0
Turbidity JTU	23	22	15	15	18	17
pH						
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: This test gave poor results in all treatments.

FLOCCULATION
JAR TEST NO. 7

Date: 10-18-67

Objectives: First of four tests to test the combination of Alum, Filtercel, Separan and Purifloc A-21.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 4.9
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	150	150	150	150
Filtercel	50	50	50	50	50	50
Separan	0.5	0.5	1.0	1.0	2.0	2.0
Turbidity JTU	3.3	3.1	3.0	2.9	3.6	3.2
pH						
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: The varying of Separan from 0.5 to 2 did not make much difference.

FLOCCULATION
JAR TEST NO. 8

Date: 10-18-67

Objectives: First of four tests to test the combination of Alum, Filtercel, Separan and Purifloc A-21.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 5.6
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	150	150	150	150
Filtercel	0	0	25	25	50	50
Separan	1.5	1.5	1.5	1.5	1.5	1.5
Turbidity JTU	2.7	2.5	2.7	2.75	2.8	4.0
pH						
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: Addition of diatomite as a weighting agent did not produce water of lower turbidities.

FLOCCULATION
JAR TEST NO. 9

Date: 10-18-67

Objectives: First of four tests to test the combination of Alum, Filtercel, Separan and Purifloc A-21.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	100	100	150	150	220	180
Filtercel	0	0	0	0	0	0
Separan	1.0	1.0	1.5	1.5	2.0	2.0
Turbidity JTU	2.2	2.4	1.6	1.8	1.4	1.5
pH		6.4		6.35		6.3
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: Better results were obtained with higher Alum dosages.

FLOCCULATION
JAR TEST NO. 10

Date: 10-18-67

Objectives: Comparison Purifloc coagulants with Separan NP10.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 6.3
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	150	150	150	150
Filtercel	0	0	0	0	0	0
Separan	1.5	1.5	0	0	0	0
Purifloc A-21	0	0	1.0	1.0	2.0	2.0
Turbidity JTU	3.1	2.7	1.2	1.9	1.6	1.4
pH						
Settling Time (min)						
Floatables						
Floc Appearance						

Comments: Samples treated with purifloc showed a poorer floc than those treated with Separan, yet the decanted water showed lower turbidity.

FLOCCULATION
JAR TEST NO. 11

Date: 10-19-67

Objectives: To test the effectiveness of purifloc coagulants in various formulations. Purifloc was added first and stirred for 1 or 2 min. Then Alum added and stirred 5 min. Slow flocculation was generally for 5 min and settling for 10 min.

Feedwater:

pH 5.4
Turbidity

Additives (ppm)	A	B	C	D	E	F
Purifloc A-21	5	5	5	5	5	5
Alum	0	0	50	50	100	100
Turbidity JTU	.81	.67	1.5	1.7	2.7	2.4
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: In the presence of the anionic purifloc the addition of Alum increased the turbidity of the decanted liquid.

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FLOCCULATION
JAR TEST NO. 12

Date: 10-19-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH 5.3
Turbidity

Additives (ppm)	A	B	C	D	E	F
Purifloc A-21	3	3	4	4	5	5
Turbidity JTU	1.1	.83	.89	.86	.86	.83
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: This test shows that 3 ppm of purifloc is almost as good as 5 ppm.

FLOCCULATION
JAR TEST NO. 13

Date: 10-19-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH
Turbidity

Additives (ppm)	A	B	C	D	E	F
Purifloc A-21	1	1	2	2	3	3
Alum	50	50	50	50	50	50
Turbidity JTU	1.4	1.6	1.4	1.3	1.4	1.5
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: This test showed that the turbidity remaining from 50 ppm of Alum was about the same whether the purifloc is 1, 2, or 3 ppm.

FLOCCULATION
JAR TEST NO. 14

Date: 10-19-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH
Turbidity

Additives (ppm)	A	B	C	D	E	F
Purifloc A-22	2	2	3	3	5	5
Turbidity JTU	3.4	3.5	3.0	2.1	2.1	2.4
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: Purifloc A-22 produced higher turbidities than Purifloc A-21, see Test No. 13.

FLOCCULATION
JAR TEST NO. 15

Date: 10-19-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH 5.2
Turbidity

Additives (ppm)	A	B	C	D	E	F
Primafloc A-23	1	2	3	4	5	6
Turbidity JTU	1.3	.83	.84	.71	.72	.80
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: Primafloc produced low turbidities but the floc was smaller and settled more slowly than for purifloc A-21. See test No. 13.

FLOCCULATION
JAR TEST NO. 16

Date: 10-19-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH 5.1
Turbidity

Additives (ppm)	A	B	C	D	E	F
Chlorine	5	5	5	5	5	5
Purifloc A-21	3	3	4	4	5	5
Turbidity JTU	.98	1.1	1.2	1.2	1.2	1.4
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: 3 ppm of A-21 does as well as 4 or 5.

FLOCCULATION
JAR TEST NO. 17

Date: 10-19-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH 5.0

Turbidity

Additives (ppm)	A	B	C	D	E	F
Chlorine	5	5	5	5	5	5
Purifloc A-21	4	4	4	4	4	4
Ferric Chloride	2.5	2.5	50	50	75	75
Turbidity JTU	5.6	6.0	13	12	17	18
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: Ferric chloride shows very poor results. It might do better at a higher pH.

FLOCCULATION
JAR TEST NO. 18

Date: 10-20-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH 5.2
Turbidity

Additives (ppm)	A	B	C	D	E	F
Chlorine	0	0	0	23	23	23
Purifloc A-21	2	3	4	2	3	4
Turbidity JTU	3.2	2.8	2.8	2.3	2.5	2.8
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: Chlorinated and unchlorinated samples behaved similarly.

FLOCCULATION
JAR TEST NO. 19

Date: 10-20-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

Feedwater:

pH 5.0
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	100	150	200	100	150	200
Purifloc A-21	2	3	4	4	6	8
Turbidity JTU	3.6	3.3	2.5	3.5	3.6	3.4
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: 4 ppm purifloc A-21 was as effective in producing low turbidities as higher concentrations.

FLOCCULATION
JAR TEST NO. 20

Date: 10-20-67

Objectives: Comparison purifloc coagulants with Separan NP 10.

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 5.1
Turbidity

Additives (ppm)	A	B	C	D	E	F
Purifloc A-21	2	4	6	8	0	0
Purifloc N-12	0	0	0	0	2	8
Turbidity JTU						
pH						
Settling Time						
Floatables						
Floc Appearance						

Comments: Purifloc N-12 gave better results than Purifloc A-21.

FLOCCULATION
JAR TEST NO. 21

Date: 10-30-67 1130 Hrs.

Objectives: Comparison of Calgon 252, Nalco 670 and Dow A-21.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.15
Turbidity 3

Additives (ppm)	A	B	C	D	E	F
Nalco 670	0	0	2	4	0	0
Dow A-21	0	0	0	0	2	4
Calgon 252	2	4	0	0	0	0
Turbidity JTU	3	2.8	3.8	4.2	2.9	3.8
pH	7.1	7.1	7.1	7.1	7.1	7.1
Settling Time						
Floatables						
Floc Appearance						

Comments: Calgon 252 formed floc immediately and the floc was dense. Nalco 670 and Dow A-21 formed finer floc. Dow A-21 was superior to Nalco 670 as to settling. After stirring the Calgo was settled on the 4 ppm and almost settled on the 2 ppm.

FLOCCULATION
JAR TEST NO. 22

Date: 10-31-67 1400 Hrs.

Objective: Comparison of Bentonite Clay and Calgon 252

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.15
Turbidity 12

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	0	50	0	50	0	50
Calgon 252	2	2	4	4	6	6
Turbidity JTU	8.5	4.8	8.3	6.0	8.8	7.0
pH	7.1	7.1	7.1	7.1	7.1	7.1
Settling Time						
Floatables						
Floc Appearance						

Comments: Calgon 252 produced better floc and the floc settled better with each addition of Calgon 252. Small floc formed with no Bentonite Clay and larger floc where clay was added. B, D, F had small amount of large floc floating at surface. A, C, E had finer floc.

FLOCCULATION
JAR TEST NO. 23

Date: 10-31-67 1500 Hrs.

Objectives: Comparison of Bentonite Clay, Dow A-21, Filter Cell and Calgon 252.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.15
Turbidity 13

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	0	50	0	0	50	0
Dow A-21	0	0	0	4	4	4
J.M. Filter-Cel	0	0	50	0	0	50
Calgon 252	4	4	4	0	0	0
Turbidity JTU	9.3	6.8	11	9.2	6.1	14
pH	7.1	7.1	7.1	7.1	7.1	7.1
Settling Time						
Floatables						
Floc Appearance						

Comments: Samples with Filter-Cel showed a better floc formation than samples with no weighting agent. Bentonite Clay produced the lowest turbidities. Dow A-21 had very small floc in all 3 tests. It was the same size and nature as Calgon 252 with no additives.

FLOCCULATION
JAR TEST NO. 24

Date: 11-1-67 0800 Hrs.

Objectives: Comparison of Bentonite Clay, Alum, and Calgon 252.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.2
Turbidity 12.5

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	0	50	50	0
Alum	0	50	50	0	50	50
Calgon 252	1	1	1	2	2	2
Turbidity JTU	4.7	5.8	5.5	5.0	5.2	6.5
pH	7.1	6.8	6.8	7.1	6.8	6.8
Settling Time						
Floatables						
Floc Appearance						

Comments: Calgon 252 and Bentonite Clay (without alum) produced a more dense floc and less turbid products than formulations with alum. Some floc stayed on the surface.

FLOCCULATION
JAR TEST NO. 25

Date: 11-2-67 0730 Hrs.

Objectives: Comparison of Bentonite Clay, Alum, Calgon 252 and Nalco 680.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 6.6
Turbidity 12.5

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Alum	50	100				
Calgon 252	2	2	2	2	2	2
Nalco 680 (Sodium Aluminate)					50	100
Turbidity JTU	0.97	1.4	6.0	4.5	4.1	3.4
pH	6.6	6.4	6.9	6.9	7.5	7.8
Settling Time (min)	45 sec	1-1/2	1-1/4	1-1/2	10	9
Floatables	none	none	yes	yes	none	none
Floc Appearance	very large	large	large	large	small	small

Comments: Samples with Alum were superior in settling time and turbidity. This is in conflict with results obtained in Test 24.

FLOCCULATION
JAR TEST NO. 26

Date: 11-2-67 1400 Hrs.

Objectives: Comparison of Bentonite Clay, Alum, Calgon 252, Nalco 672 and Nalco 673.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 6.85
Turbidity 13

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Alum	50	50	50	50	50	50
Calgon 252	1	2	0	0	0	0
Nalco 672	0	0	1	2	0	0
Nalco 673	0	0	0	0	1	2
Turbidity JTU	2.5	2.4	1.8	1.8	1.7	1.9
pH	6.6	6.6	6.6	6.6	6.6	6.6
Settling Time	1:40	30 sec	2:30	2:00	3:15	2:30
Floctubles	Medium	Large	Small	Small	Small	Small
Floc appearance	0	0	0	0	0	0

Comments: Samples with Calgon 252 were superior in floc size and settling time, but not in turbidity, to Nalco products. The 2 ppm Calgon 252 produced larger floc and settled faster than 1 ppm. Turbidity remained equal. One or two ppm Nalco did not change floc much.

FLOCCULATION
JAR TEST NO. 27

Date: 11-3-67 1100 Hrs.

Objectives: Comparison of Bentonite Clay, Alum, Calgon 252 and Celite.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.0
Turbidity 14

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	0	50	0	50	0	50
Alum	0	0	50	50	0	0
Calgon 252	1	1	2	2	2	2
Celite 535	50	0	50	0	50	0
Turbidity JTU	13	4.8	6.2	3.7	12	4.2
pH	6.9	6.95	6.6	6.7	6.9	6.9
Settling Time (min)	10+	10+	45 sec	45 sec	10+	10+
Floatables	Very Small	Small	Uneven Med. to Large	More Floc than C Large	Very Small	Small
Floc Appearance	0	yes	Small Amount	yes	none	yes

Comments: Samples with Alum settled faster and had lower turbidities than samples without alum. Bentonite Clay produced lower turbidities than Celite 535.

FLOCCULATION
JAR TEST NO. 28

Date: 11-5-67 1500 Hrs.

Objectives: Determine whether increased dosages of Calgon 454 or Alum would improve clarifier effluent quality.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 6.95
Turbidity 12.5

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Alum	50	100	50	100	50	100
Calgon 454	2	2	4	4	6	6
Turbidity (JTU)	12	3.2	2.3	3.3	3.3	2.5
pH	6.6	6.35	6.6	6.2	6.6	6.2
Settling Time	Already settled	4 min	A.S.	30 sec	A.S.	30 sec
Floatables	yes	no	yes	yes	yes	yes
Floc Appearance	Large	Small	Very Large	Large	Very Large	Large

Comments: Samples with 50 ppm Alum settled faster than samples with 100 ppm Alum. Four ppm Calgon 454 produced lowest turbidities.

FLOCCULATION
JAR TEST NO. 29

Date: 11-7-67 0630 Hrs.

Objectives: Comparison of different formulations using Calgon D228, Calgon 252, and Alum.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 7.2
Turbidity 13

Additives (ppm)	A	B	C	D	E	F	Order of Addition
Bentonite Clay	50	50	50	50			2
Alum	50	0	0	0			1
Calgon 228D	0	1/2	1	2			4
Calgon 252	1	1/2	1	2			3
Turbidity JTU	1.4	1.2	1.2	1.25			
pH	6.8	7.2	7.2	7.2			
Settling Time	2 min 30 sec	2 min 30 sec	Settled	Settled			
Floatables	Med.	Med.	Large	X-Large			
Floc Appearance	none	yes	yes	yes			

Comments: Calgon D-228, in concentrations of 1 and 2 ppm, produced faster settling floc than 50 ppm Alum.

FLOCCULATION
JAR TEST NO. 30

Date: 11-8-67

Objectives: To determine whether sequence of addition of coagulants makes a significant difference on results.

50 rpm's for 5 min
20 rpm's for 10 min
0 rpm's for 10 min

Feedwater:
pH 6.85
Turbidity 7

Additives (ppm)	A	Order of Addition	B	Order	C	Order	D	Order	E	Order	F	Order
Calgon 252	1	1	1	3	1	3	1	2	1	2	1	1
Calgon 228D	1	2	1	1	1	2	1	1	1	3	1	3
Bentonite Clay	50	3	50	2	50	1	50	3	50	1	50	2
2 min time interval between coagulant additions												
Turbidity	1.2		1.3		1.0		1.5		1.2		1.6	
pH	7.1		6.95		6.9		6.9		6.9		6.9	
Settling Time	set.		30 sec		30 sec		set.		set.		set.	
Floatables	yes		yes		yes		yes		yes		yes	
Floc Appearance	3-4		5-6		5-6		3-4		1		2	

Comments: Test showed the desirability of addition of Bentonite Clay first for seeding agent. Adding Calgon D-228 before the 252 gave better clarity although a slightly slower settling rate. Confirms tests run by John Slyker with same materials.

FLOCCULATION
JAR TEST NO. 31

Date: 11-8-67

Objectives: To determine whether time interval between addition of coagulants makes a significant difference on results.

50 RPM's for 7 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH
Turbidity

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Time Interval between 1st and 2nd Coagulants	*	*	*	1 min	3 min	5 min
Calgon 228D	1	1	1	1	1	1
Time Interval between 2nd and 3rd	1 min	3 min	5 min	*	*	*
Calgon 252	1	1	1	1	1	1
Turbidity	2.5	2.4	2.5	2.2	2.4	2.5
pH	7	7	7	7	7	7
Settling Time	Settled	S	S	S	S	S
Floatables	Yes	Yes	Yes	Yes	Yes	Yes
Floc Appearance	V Lge	VL	VL	VL	VL	VL

Comments: Jars C and F took longer to reach floc size during 50 rpm mixing than other jars. No significant difference was observed on floc density or turbidities.

*Immediate addition.

FLOCCULATION
JAR TEST NO. 32

Date: 11-9-67

Objectives: To determine whether Calgon D228 and 252 can be added simultaneously. If this can be done, clay can be added first in plant operation as a seeding agent.

50 RPM's for 10 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 7.1
Turbidity 6

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Time Interval between 1st and 2nd Coagulants	1 min	1 min	1 min	1 min	1 min	1 min
Calgon 228D	1	1	1	1	1	1
Time Interval between 2nd and 3rd Coag.	1 min	*	2 min	*	3 min	*
Calgon 252	1	1	1	1	1	1
Turbidity	1.8	1.7	1.7	1.6	1.6	1.7
pH	7.0	7.0	7.0	7.0	7.0	7.0
Settling Time (min)	2	1	1	2	2	1
Floatable:	Med	Med	Med	Med	Med	Med
Floc Appearance	Yes	Yes	Yes	Yes	Yes	Yes

Comments: Tests showed no effect on floc of turbidity of different addition intervals.

*D228 and 252 mixed together and added simultaneous.

FLOCCULATION
JAR TEST NO. 33

Date: 11-9-67

Objectives: To determine if simultaneous addition of Calgon 252 and Alum would improve clarifier performance. If this can be done, Bentonite Clay will function as a seeding agent.

50 RPM's for 10 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 7.2
Turbidity

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Time Interval between 1st and 2nd Coagulants	1 min	1 min	2 min	2 min	3 min	3 min
Alum	50	50	50	50	50	50
Time between 2nd and 3rd	*	1 min	*	2 min	*	3 min
Calgon 252	3	3	3	3	3	3
Turbidity	1.8	2.8	2.0	1.9	2.0	2.2
pH	7.1	7.1	7.1	7.1	7.1	7.1
Settling Time (min)	N.D.	2-1/2	N.D.	2-1/2	N.D.	2-1/2
Floatables	0	0	0	0	0	0
Floc Appearance	Small	Med	Small	Med	Small	Med

Comments: Actual settling time for floc not detectable for samples where Alum and Calgon 252 were mixed. Floc was larger where Alum and Calgon 252 were not mixed.

*Calgon 252 and Alum mixed together and added simultaneously.

FLOCCULATION
JAR TEST NO. 34

Date: 11-10-67 1030 Hrs

Objectives: To check action of Alum and Separan on feed water and compare it to Calgon 252 and 228-D on same.

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 7.0
Turbidity 6

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Alum	100	100	100	0	0	0
Separan NP 10	1	2	3	0	0	0
Calgon 252	0	0	0	1/2	1	2
Calgon 228D	0	0	0	1/2	1	2
Turbidity	2.4	2.5	4.7	2.3	2.0	1.9
pH	6.5	6.5	6.5	7.0	7.0	7.0
Settling Time (min)	3-1/2	2	2	3-1/2	1	Settled
Floatables	0	0	0	Yes	Yes	Yes
Floc Appearance	Small	Small	Small	Small	Med	Large

Comments: Calgon additives were superior to Alum and Separan in floc size, clarity and settling.

FLOCCULATION
JAR TEST NO. 35

Date: 11-10-67 1130 Hrs

Objectives: Compare Calgon 25 to Bentonite Clay

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 7.0
Turbidity 7.0

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	0	50	0	50	0
Calgon 25	0	50	0	50	0	50
Calgon 252	1	1	2	2	3	3
Calgon 228D	1	1	2	2	3	3
Turbidity	2	3.8	2.1	3.8	2.2	3.8
pH	7	7	7	7	7	7
Settling Time	1 min	30 sec	Settled	15 sec	Settled	Settled
Floatables	Yes	Yes	Yes	Yes	Yes	Yes
Floc Appearance	Lg	Lg	X Lg	X Lg	X Lg	X Lg

Comments: The Aqua-Gel Bentonite Clay was superior to the Calgon 25 for producing low turbidities. There was no difference in floc appearance.

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FLOCCULATION
JAR TEST NO. 36

Date: 11-13-67 1400 Hrs

Objectives: To determine whether A-21 can be substituted for Calgon 228D.

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 7.2
Turbidity 4.0

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	-
Alum	50	0	50	0	0	
Calgon 228D	0	0	0	3	3	-
Calgon 252	3	3	0	3	0	-
Purifloc A-21	0	3	3	0	3	-
Turbidity	1.3	1.7	1.5	1.3	1.3	-
pH	6.8	7.2	6.8	7.2	7.2	-
Settling Time (min)	1-1/2	Not Settled	Ns	Settled	S	-
Floatables	0	0	0	Yes	Yes	-
Floc Appearance	Med	Sm	Sm	X Lg	X Lg	-

Comments: A-21 did not perform as well as Calgon 228D. Turbidity did not differ greatly but floc size was better in D and E.

FLOCCULATION
JAR TEST NO. 37

Date: 11-15-67 1100 Hrs

Objectives: To compare former additions, with present and additives planned for near future. Also served as a demonstration for Tom Mallonee.

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 7.0
Turbidity

Additives (ppm)	A	B	C	D	E	F
Alum	150	150	50	50	0	0
Separan NP 10	1	1	0	0	0	0
Bentonite Clay	50	50	50	50	50	50
Calgon 252	0	0	3	3	2	2
Calgon 228D	0	0	0	0	2	2
Turbidity JTU	2.7	3.5	1.3	1.3	.60	.63
pH	5.9	5.9	6.55	6.5	6.98	6.99
Settling Time	Not Settled	Not Settled	2 min	2 min	Settled	Settled
Floatables	No	No	No	No	Yes	Yes
Floc Appearance	Small	Small	Med	Med	X Lge	X Lge

Comments: Calgon 228D and 252 produced better results than Calgon 252 and Alum.

FLOCCULATION
JAR TEST NO. 38

Date: 11-28-67 2300 Hrs

Objectives: Compare flocculation of Bentonite Clay, Calgon 228D and Calgon 252 at different pH levels.

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH
Turbidity

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	50	50	50	50	50
Calgon 228D	1	2	1	2	1	2
Calgon 252	1	2	1	2	1	2
Turbidity JTU	1.5	2.0	1.6	2.0	1.5	2.0
Initial pH	6.5	6.5	6.0	6.0	5.5	5.5
pH	6.8	6.8	6.3	6.3	5.9	5.8
Settling Time	Settled	S	S	S	S	S
Floatables	Yes	Yes	Yes	Yes	Yes	Yes
Floc Appearance	X Lge	X Lge	X-L	X-L	X-L	X-L

Comments: Floc formed slower with lower pH values, although all jars did form floc before test was completed. Jar E didn't form the one lump; but had floc particles varying in size although all were quite large.

FLOCCULATION
JAR TEST NO. 39

Date: 12-14-67 1500 Hrs

Objectives: To recheck Bentonite Clay versus Calgon 25 at different dosages.

100 RPM's for 2 min
50 RPM's for 5 min
20 RPM's for 10 min
0 RPM's for 10 min

Feedwater:
pH 5.8
Turbidity

Additives (ppm)	A	B	C	D	E	F
Bentonite Clay	50	0	100	0	150	0
Calgon 25	0	50	0	100	0	150
Calgon 228D	1	1	1	1	1	1
Calgon 252	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2
Turbidity JTU	2.3	2.1	2.3	2.0	2.3	1.5
pH	5.9	5.95	6.0	6.1	6.1	6.2
Settling Time (min)	1-1/2	1	1	1	1	1
Floatables	Yes	Yes	Yes	Yes	Yes	Yes
Floc Appearance	Med	Lg	Med	Lg	Med	Lg

Comments: Calgon 25 formed larger floc than Bentonite Clay. Turbidities of samples using Calgon 25 were slightly lower.

WASTE WATER DEMONSTRATION UNIT AT ODESSA, TEXAS

DAILY DATA RECORD SHEET

Date _____

SKIMMER

	Feed	Effluent	Sludge
Time Samples Taken			
Settleable Solids			
lbs. Solids in Sludge (Calculated)			

Feed Conductivity _____. TDI _____

Effluent pH _____. Temp. _____ °F.

Lab. Check - pH _____ Conductivity _____

Sludge (gals) - Float _____ Settled _____ Total _____

COOLING TOWER

Pump - on ___. Off ___. Fan - Auto ___ Man. ___ off ___

Temp. (°F.) - Control Setting _____ Actual _____

EQUALIZING TANK

Level ___. Turbidity ___. Res Chlorine ___

pH - Recorder _____ Lab. Check _____

Settleable Solids _____. _____

CLARIFIER

Product Turbidity _____. Settleable Solids ___

Product Res. Chlorine _____

Sludge - _____ gals. Settleable Solids _____

lbs. Solids in Sludge (Calculated) _____

Blanket Level Time	Inches

COAGULANT FEEDERS

	P-7	P-8	Level Readings Time	T-7	T-8
Coagulant					
% Solution					
Gal/hour					
Actual ppm					
Desired ppm					

CHLORINE FEEDERS

	No. 1	No. 2	Total
Injector Location			
Setting #/Day			
Desired Rate ppm			

SULFURIC ACID FEEDER

Stroke Setting _____ Carboys used ___

WEIGHTING AGENT FEEDER

Type _____ Bags used ___

Feeder Setting ___ Rate gms/min ___

ppm Desired _____. Actual _____

D.E. BODY FEEDER

Feed Rate - _____ gph _____ ppm

Type of D.E. _____

% Slurry _____ Batches Made _____

FA-1 Level Time	Inches

D.E. FILTER

	D.E. Type	lb. per Percent	Time	Filter No.	Backwashes No.	Gals
1st Coat						
2nd Coat						
3rd Coat						
Total lb. D.E. Used						
Eff. Turbidity						
			Totals			

Backwash Settleable Solids _____

lbs. Solids in backwash (calculated) _____

REVERSE OSMOSIS UNIT

Feed Temp. ___ °F. Press ___. R.O. Press ___

Product Meter Reading _____ gals @ _____ Hrs

Production Rate _____ gpd. Flux _____ gfd

Downtime Hrs. - Sched. _____ Unsched. _____

TDI Permeation _____ %. Cell Diff. Press. ___

	Feed	Reject	Product
Conductivity (Recorder)			
Conductivity (Lab. Check)			
TDI (calculated)			
Residual Chlorine			
Turbidity			
pH			
Calcium *			
Total Alkalinity			
Stability Index			
Bicarbonate (Calc.)			

Flush Cycle - every ___ Hrs for ___ min

Filter Cartridges Used _____

* Composite Sample

WASTE WATER DEMONSTRATION UNIT AT ODESSA, TEXAS

WEEKLY/MONTHLY DATA RECORD SHEET Date _____

COMMERCIAL SAMPLE ANALYSES

Weekly Analyses	Skim. Feed	R.O. Feed	R.O. Prod.	% Perm
Sample No.				
Total Hardness				
Calcium				
Manganese				
Iron (1)				
Ammonia (1)				
Organic Nitrogen (1)				
Nitrate + Nitrite (1)				
Total N_2 (Calc.)				
Organic Carbon (2)				
Total Phosphate				
Chloride				

Monthly Analyses				
Sample No.				
Detergents				
Phenol (2)				
Isopropyl Alcohol (1)				
Butadiene (1)				
Styrene (1)				

GRAB SAMPLES

Weekly Analyses	Skim. Feed	R.O. Feed	R.O. Prod.	% Perm.	R.O. Reject		
Sulfates							
Coliforms (Pres.)							
Color							

WEEKLY POWER CONSUMPTION ANALYSES

R.O. Oper. Factor _____ %

	Electrical Service			R.O. Prod.
	Total	Fav	Demo	
Time of Meter Read.				
Meter Reading				
Hrs Since Last Read.				
Amt. Used or Prod.				
KWH/Hour				
KWH/M gals				
KWH/M gals X R.O. Oper. Factor				

D.E. FILTER EFFLUENT MILLIPORE TEST

Turbidity _____. ml in 15 min. _____.

WEEKLY MAINTENANCE SUMMARY

Job #	Description	Man Hrs.	Man $	Total $

MISCELLANOUS

WEEKLY RAW MATERIALS RECONCILIATION

Item	Units	Start Inv.	Purchases: Order Date	Req. No.	Date Rec'd	Amount Rec'd	Actual Ending Inv.	Data Sheet Comparisons: Usage	Calc. Ending Inv.	Calc. minus Actual
Filter Elements	Units									
Sulfuric Acid (22C#)	#									
J.M. 535 (50#)	#									
J.M. Super-Cel (50#)	#									
J.M. Filter-Cel (50#)	#									
Bentonite Clay (100#)	#									
Chlorine (150#/ctl)	#									
Calgon 252 (25#)	#									
Calgon D228 (25#)	#									

Footnotes

(1) Analyses by Pomeroy, Johnston & Bailey

(2) Analyses by Calgon Corp.

(3) Run analyses on daily composite sample.

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BENCH SCALE TEST DAILY DATA SHEET

Date _____

UNIT ASSIGNMENT

Unit	1	2	3	4	5
Test Cond.					

DESIRED TEST CONDITIONS

Test Cond.	A	B	C	D	E

FEEDWATER ANALYSES

Res. chlorine (ppm) _____

pH _____

Conductivity (micromhos) _____

TDI (Calc.) (ppm) _____

Temp. °C. _____

_____

_____

_____

ADDITIVES TANKS

Variable	Time	Unit No. 1	2	3	4	5
Additives Tank Level						
Additives Feed Rate (gph)	X					
*Additives Feed Ratio (%)	X					

PRODUCT WATER FROM TEST CELLS

Variable	Time	Unit 1 a	b	c	Ave.	Unit 2 a	b	c	Ave.	Unit 3 a	b	c	Ave	Unit 4 a	b	c	Ave	Unit 5 a	b	c	Ave
Flux (gfd)																					
Conductivity (micro)																					
TDI (Calculation) (ppm)																					
TDI Perm. (%)																					
pH																					
Res. Chlorine (ppm)																					

REJECT WATER

Variable	Time	Unit No. 1	2	3	4	5
Flow Rate (gph)	X					
pH						
Res Chlorine (ppm)						

* Additives feed ratio = $\frac{\text{Additives feed Rate}}{\text{Reject flow Rate} + .00132 \text{ Flux}}$

Comments _____

_____

_____

_____

_____

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TESTS ON WASTE WATER OF THE ODESSA INDUSTRIAL COMPLEX PREPARATORY TO OPERATION OF A DEMONSTRATION PLANT FOR INDUSTRIAL WATER RENOVATION

28 September 1967

Five samples of water were received from R. S. Dodds, El Paso Products, Odessa, Texas, on 15 September 1967, for determinations of total salts (or total cations) by the ion exchange method, and electrical conductivity. Determinations of pH were also made, this being essential to the determination of the ion concentration. Results were as follows:

Sample	pH	H^+, me/l, calc.	Specific Conductance, micromhos/cm, 25°C	Total Salts* (or Total Cations) me/l	Total Salts* Expressed as NaCl, mg/l	Ratio, Total Salts (or Cations) in me/l ÷ Conductance
1	6.92		693	6.31	369	0.00911
2	5.93		608	5.37	314	0.00883
3	3.77	0.17	574	4.43	259	0.00772
4	5.38		517	4.44	260	0.00859
5	3.85	0.14	517	3.91	229	0.00756
Average						0.00836
Average omitting low pH samples						0.00884

*Including ionized acids

The equivalent ion conductance of hydrogen ion is about six times as great as the average for the ions common in most waters. Hydrogen ion constitutes a significant part of the total cation concentration in samples 3 and 5. The measured ion concentration, and hence the ratio of ions to conductance, is lower than for the other samples. Presumably most samples to

be tested will not have such low pH values, and the ratio 0.0088 may be used for estimating total salts, in me/l, from the conductance at 25°C.

For the samples reported on 29 June 1967, having a specific conductance at 25°C averaging 12,400, the ratio was 0.0100.

For any given electrolyte, the reduction of equivalent conductance below the value at infinite dilution is approximately proportional to the square root of the concentration. Therefore, the concentration, C, of an electrolyte is related approximately to the specific conductance, L, by an equation of the form

$$C = \frac{aL}{1-b\sqrt{L}}$$

in which a and b are constants.

If the raw wastes for which data were presented in the report of 29 June 1967 and the samples here reported can be looked upon as different concentrations of the same electrolyte, the equation becomes

$$C = \frac{0.00858\ L}{1-0.00124\sqrt{L}}$$

Total salt concentrations calculated by this equation are compared with the observed concentrations in the following table:

Sample	Specific Conductance, m mhos/cm @ 25°C	Total Salts, me/l		
		Calculated	Observed	Error, %
A	11,750	116.5	117.9	- 1.2
B	13,010	130.0	123.5	+ 5.3
C	11,400	112.7	115.9	- 2.8
D	12,200	121.3	121.1	+ 0.2
E	13,700	137.5	139.6	- 1.5
1	693	6.14	6.31	- 2.7
2	608	5.38	5.37	+ 0.2
3	574	5.08	4.43	+ 14.7*
4	517	4.56	4.44	+ 2.7
5	517	4.56	3.91	+ 16.6*

*Low pH samples

The low pH samples were not used in deriving the constants for the equation.

The good agreement of the calculated and observed salt concentrations should not cause one to lose sight of the limitations of the equation. It is based upon two sets of samples widely differing in concentration, with all of the difference between the equivalent conductances attributed to the concentration effect. As a matter of fact, the two sets may differ in the proportions of ions having different mobilities. Nevertheless, the equation probably will provide sufficient practical accuracy for monitoring the various flows in the Odessa industrial waste reclamation project.

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660 South Fair Oaks Avenue, Pasadena, California 91105
Branch office in Ventura, California

14 November 1967

Aetron
Attention: Mr. Marvin Jarvis

c/o Mr. Frank Smythe
El Paso Products
P. O. Box 3986
Odessa, Texas 79760

IRON AND COPPER DETERMINATIONS ON SAMPLE, "R. O. FEED"

A sample labeled "R. O. Feed, 10/25/67" was received at our laboratory for an iron determination, and subsequent instructions requested a copper determination also. Since the question of possible interferences in the tests is of importance, different methods were used, not only to get the best results, but also to determine the capability and limitation of the methods available to you. Replicate tests were run, with results, in mg/l (ppm) as follows.

Iron by Orthophenanthroline

Unmodified sample	0.50,	0.38,	0.35
After removal of organics	0.67,	0.58	
After removal of Cu	0.00,	0.96	

Copper by Bathocuproine

Unmodified sample	3.1,	3.05
After removal of organics	3.17	
Recovery via CuS	3.07	

The results for iron are rather erratic. The tests after removal of copper appear rather meaningless; undoubtedly the iron was lost in some way in the test that showed zero. Interferences apparently have a negative effect. A larger sample could be used to get an unequivocal result. You can use the direct colorimetric test with O-phenanthroline if the result is reported as "apparent iron by O-phenanthroline," realizing that it is an indication that may be quite inaccurate.

The tests with copper are much better, all results being in a narrow range. There does not appear to be any interference with the direct use of the bathocuproine method for copper.

The copper content of the water can cause serious corrosion of iron. If the sample is representative, the water may carry 0.4 lb per day of copper. By direct displacement, it could corrode nearly that weight of iron. It is unlikely that the reaction would be anywhere near complete, so the actual direct attack would surely be much less than that. Unfortunately, when copper plates out on iron, it acts cathodically and can cause severe pitting of the iron if the water contains an oxidizing agent, such as oxygen or active chlorine compounds.

Copper ion reacts only very slowly with stainless steel under most conditions. However, the protective oxide film on stainless steel may break down under anoxic conditions and may allow rapid attack. I would recommend that you open the Hayward filter and inspect the stainless steel wire windings on the tubes to see if serious attack is occurring. Use a magnifying glass as an aid. Viewing the tubes through the sight glasses is not enough, because there may be only occasional pits developing on the wire. A single pit cutting through the wire can put the filter out of operation. At the same time, the interior of the shell can be examined to see if serious pitting is in progress there.

Very truly yours,

Richard D. Pomeroy

Richard D. Pomeroy
POMEROY, JOHNSTON AND BAILEY

RDP:kh

Pomeroy, Johnston and Bailey CIVIL AND CHEMICAL ENGINEERS

RICHARD D. POMEROY, PH.D.
CARL B. JOHNSTON
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RAYMOND C. SPOELSTRA

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Marketing and Administration

28 December 1967

Aerojet General Corporation
c/p Frank Smythe
El Paso Products Company
P. O. Box 3986
Odessa, Texas 79760

Gentlemen:

We are reporting the analytical results on three samples of water, identified below, received by us on 22 December 1967.

Constituent	1212A Skimmer Feed Composite 12/8 to 12/12/67	1212C R.O.Feed Composite 12/8 to 12/12	1212C R.O.Product Composite 12/8 to 12/12/67
*Iron, Fe, mg/l	0.70	1.46	0.64
Nitrogen			
Ammoniacal (as N), mg/l	149	141	46
Nitrite (as N), mg/l	0.88	0.28	0.82
Nitrate (as N), mg/l	19.2	18.1	4.5
Organic (as N), mg/l	21.0	27.8	11.8
**Isopropyl Alcohol, mg/l	9.7	11.1	4.1
Butadiene, mg/l	0.2	0.4	0.03
Styrene, mg/l	5.3	9.7	4.4

*In solution at time of analysis.
**Values for Isopropyl, Butadiene, Styrene ± 10%.

Respectfully submitted,

Raymond C. Spoelstra
POMEROY, JOHNSTON AND BAILEY

RCS:kh